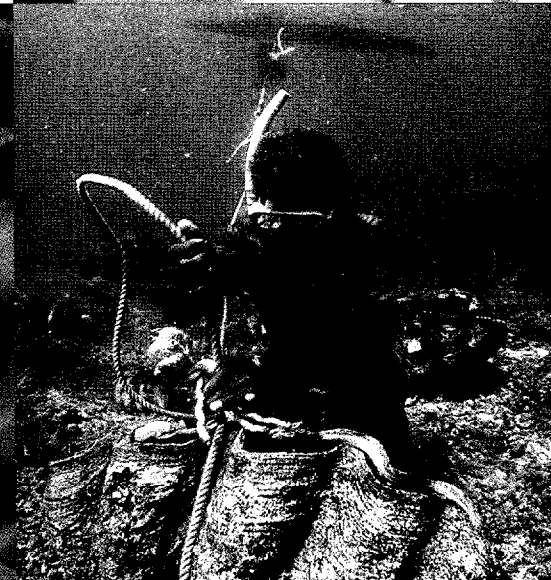




Consultative Group on International Agricultural Research

CGIAR ANNUAL REPORT 1993–1994



“We are at a crossroads, and it is incumbent upon us to act. We must act not to save a bureaucratic structure, not to stabilize an instrument of our policy, not even to save the centers of excellence of the CGIAR and to strengthen the national systems of research and extension that I have made a broad commitment to help. We must act for the poor and the hungry of the world, and for the children of the poor and the marginalized of today, who will be the hungry a decade from now, if we do not act now.”

—*CGIAR Chairman Ismail Serageldin, in his opening address
at the CGIAR Mid-Term Meeting, New Delhi, May 1994*



CGIAR

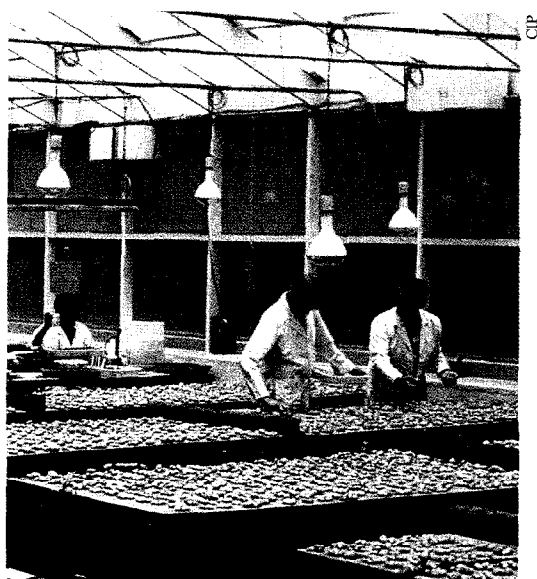
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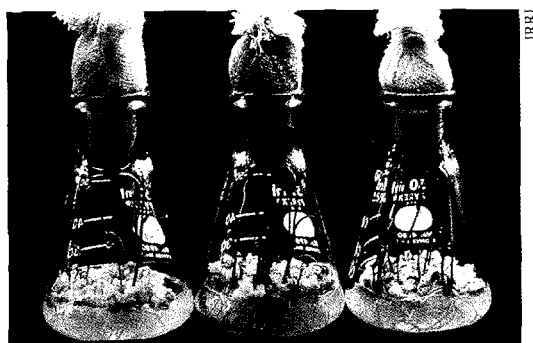
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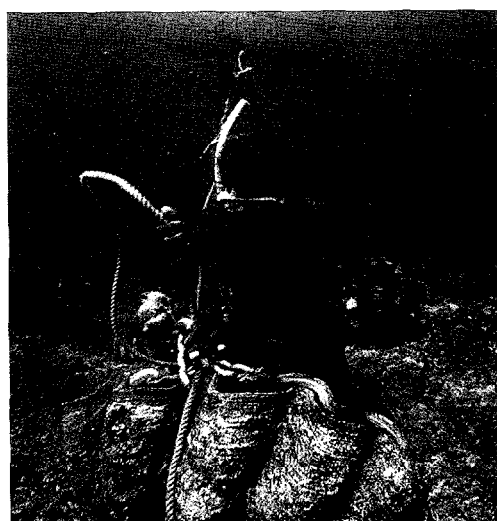


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Introduction

The CGIAR ended the year 1993 facing a potential crisis that threatened to undermine the continuity and effectiveness of its research. By mid-1994 it had overcome the short-term aspects of the crisis and moved well into a long-term program of revitalization. This annual report of the CGIAR, therefore, covers the period 1993–94, taking the Group's 1994 Mid-Term Meeting (May 23–27 in New Delhi) as its closing point, enabling us to inform readers of the important events that took place in the first half of 1994.

The turbulence experienced by the CGIAR was caused by a significant decline of funding for CGIAR programs since 1992. The decline appeared certain to continue into 1994 and 1995. This adverse trend threatened the integrity of research at the CGIAR centers, which faced the prospect of eliminating programs and further reducing staff.

To reverse the trend and avert the crisis, CGIAR Chairman Ismail Serageldin inaugurated a series of countermeasures, which he spelled out in detail at the Mid-Term Meeting. The most urgent of these was an emergency plan to stabilize funding. Mr. Serageldin received a positive response from the CGIAR membership, and 1994 funding rose by some \$48 million from an estimated \$215 million, thus ensuring that the year's research agenda will be fully funded. This was made possible by additional funding from donors, together with matching funds from the World Bank.

The CGIAR Vision

What began at New Delhi was not merely a financial rescue operation but a program of renewal, recommitment, and rededication to the long-term vision of the CGIAR. That program will culminate in an international agricultural

research "summit meeting" early next year, when representatives of the international community will be invited to launch the "new" CGIAR.

A renewal and redefinition of the vision of the CGIAR, refocusing of the research agenda, modifications in governance, and re-engineering of funding systems are among the changes set in motion.

The vision of the CGIAR is to contribute to the alleviation of poverty and the elimination or reduction of hunger. The CGIAR will articulate this vision to demonstrate that agriculture is a catalyst of sustainable development with a multifaceted impact on poverty, hunger, food security, and natural resource management. Agricultural research, which creates new technologies, is an essential precondition for agricultural development.

Refocusing the Research Agenda

The CGIAR is part of a wider global research effort, involving actors from both South and North. To provide farmers and scientists of the South with the maximum possible support, the CGIAR will sharply focus its research agenda, taking into account the programs of other components of the global research system. The CGIAR centers will conduct strategic research in areas that are truly of trans-border significance and in which they have a clear, comparative advantage.

Strengthening Partnerships

In its founding resolution, the CGIAR committed itself to meeting "the needs of developing countries." Toward this end, a critical mass of some 1,000 top-quality scientists, drawn from many nationalities, today works solely on the problems of developing countries at CGIAR centers. The "public goods" nature of their



ICRAF/A. Njenga

research makes it accessible to all. No comparable group of scientists is dedicated solely to meeting the needs of developing countries, uninhibited by politics, and equally involved with the summits of scientific endeavor and the grass-roots of farm activity. Genuine “ownership” of the CGIAR system by partners in developing countries is essential to the continued vigor and effectiveness of this effort. The CGIAR aims, therefore, to develop mechanisms for greater developing-country participation in deliberations and agenda setting, as well as in research programs.

Governance and Management

Over time, the CGIAR “model” of informal collegiality and consensus building has acquired such a positive reputation that it has been considered for replication in other sectors. But today’s challenges cannot always be met with yesterday’s traditions. The existing structure of governance has lasted more than two decades. A new structure must be able to serve the needs of stakeholders and beneficiaries for at least the next two decades. Change will therefore be undertaken with careful preparation and a judicious weighing of options, so that past and present strengths are preserved. The objectives of change are to create a more “open” CGIAR system, to widen CGIAR membership, to ensure that meet-

ings are always businesslike, and to bring decisiveness and speed into the Group’s decision making.

Financial Mechanisms and Strategies

In recent years, the effectiveness of the CGIAR centers has been hampered by a diminution of funds for their core research agenda and the diversion of funds for activities peripheral to that agenda. The CGIAR expects that by taking a matrix approach to setting the research agenda, allocating responsibilities for research programs among the centers, and securing appropriate levels of funding, it will be possible to introduce a more transparent, predictable, and stable system of financing.

The purpose of these efforts is to ensure that the CGIAR remains an effective instrument of development. As a nonpolitical, publicly funded, international agricultural research system with proven capacity, the CGIAR is uniquely positioned to play that role. The account of research in progress that is encapsulated in this report indicates both the breadth and sweep of what the CGIAR centers undertake. The continuation of those efforts is at the heart of the CGIAR’s commitment to help serve the world’s poor and hungry.

Alexander von der Osten
Executive Secretary

The Consultative Group on International Agricultural Research (CGIAR)

The Consultative Group on International Agricultural Research (CGIAR) is an informal association of 42 public and private sector donors that supports a network of 18 international agricultural research centers. The Group was established in 1971.

CGIAR centers have trained more than 45,000 agricultural scientists during the past 22 years. The types of training provided ranged from midlevel regional courses to postdoctoral programs at CGIAR centers. Many scientists from developing countries who were trained at CGIAR centers form the nucleus of and provide leadership to national agricultural research systems in their own countries.

The international centers supported by the

CGIAR are part of a global agricultural research system. The CGIAR functions as a guarantor to developing countries, ensuring that international scientific capacity is brought to bear on the problems of the world's disadvantaged peoples.

Programs carried out by CGIAR-supported centers fall into six broad categories:

- **Productivity Research**

Creating or adopting new technologies (such as the "dwarf" varieties of wheat and rice that brought about Asia's and Latin America's green revolution) to increase productivity on farmers' fields

- **Management of Natural Resources**

Protecting and preserving the productivity of natural resources on which agriculture depends

- **Improving the Policy Environment**

Assisting developing countries to formulate and carry out effective food, agriculture, and research policy

- **Institution Building**

Strengthening national agricultural research systems in developing countries

- **Germplasm Conservation**

Conserving germplasm and making it available to all regions and countries

- **Building Linkages**

Helping to create or strengthen linkages between developing-country institutions and other components of the global agricultural system

Food productivity in developing countries has increased through the combined efforts of the CGIAR centers and their associates in developing countries. The same efforts have brought about a range of other benefits, such as increased farm income, reduced prices of food, better food distribution systems, better nutrition, more rational policies, and stronger institutions.



CGIAR Centers



With improved livestock management, ICARDA has raised lambing percentages in Awassi ewes.

CIAT

Centro Internacional de Agricultura Tropical
Apartado Aereo 6713, Cali, Colombia. Founded 1967. To contribute to the alleviation of hunger and poverty in tropical countries by applying science to the generation of technology that will lead to lasting increases in agricultural output while preserving the natural resource base. Research in germplasm development in beans, cassava, tropical forages, and rice for Latin America; and research in resource management in humid agroecosystems in tropical America: hillsides, forest margins, and savannas.

CIFOR

Center for International Forestry Research
P.O. Box 6596, JKPWB Jakarta 10065, Indonesia. Founded 1993. To promote the sustained well-being of people in developing countries, particularly in the tropics, through collaborative strategic and applied research in forest systems and forestry, and by promoting the adoption of improved technologies and management practices.

CIMMYT

Centro Internacional de Mejoramiento de Maíz y Trigo Lisboa 27, P.O. Box 6-641, 06600 Mexico, D.F., Mexico. Founded 1966. To help the poor by increasing the productivity of resources committed to maize and wheat in developing countries while protecting the environment, through agricultural research and in concert with national research systems.

CIP

Centro Internacional de la Papa Apartado 5969, Lima, Peru. Founded 1970. To contribute to increased food production, the generation of sustainable and environmentally sensitive agricultural systems, and improved human welfare by conducting coordinated, multidisciplinary research programs on potato and sweetpotato, carrying out worldwide collaborative research and training, catalyzing collaboration among countries in solving common problems, and helping scientists worldwide to respond flexibly and successfully to changing demands in agriculture.

ICARDA

International Center for Agricultural Research in the Dry Areas P.O. Box 5466, Aleppo, Syria. Founded 1975. To meet the challenge posed by a harsh, stressful, and variable environment in which the productivity of winter rainfed agricultural systems must be increased to higher sustainable levels; in which soil degradation must be arrested and, possibly, reversed; and in which water use efficiency and the quality of the fragile environment need to be ensured.

ICLARM

International Center for Living Aquatic Resources Management MC P.O. Box 2631, Makati Central Post Office, 0718 Makati, Metro Manila, Philippines. Founded 1977. To improve production and management of aquatic resources for sustainable benefits of present and future generations of low-income users (producers and consumers) in developing countries through international research and related activities and in partnership with national agricultural research systems by improving the biological, socioeconomic, and institutional management mechanisms for sustainable use of aquatic resource systems, by devising and improving production systems that will provide increasing yet sustainable yields, and by strengthening national programs to ensure sustainable development of aquatic resources.

ICRAF

International Centre for Research in Agroforestry United Nations Avenue, P.O. Box 30677, Nairobi, Kenya. Founded 1977. To mitigate tropical deforestation, land depletion, and rural poverty through improved agroforestry systems.

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics Patancheru P.O., Andhra Pradesh 502 324, India. Founded 1972. To conduct research leading to enhanced sustainable food production in the harsh conditions of the semiarid tropics. ICRISAT's main crops (sorghum, finger millet, pearl millet, chickpea, pigeonpea, and groundnut) are not generally known in the world's more favorable agricultural regions, but they are vital to life for the one-sixth of the world's population that lives in the semiarid tropics. ICRISAT research is conducted in partnership with the national agricultural systems. It encompasses



A mud wasp attacking a pod borer larva, a voracious pest that devastates a wide range of crops. Encouraging natural predators is an important facet of integrated pest management practices, contributing to the reduction of crop losses.

the management of the region's limited natural resources to increase the productivity, stability, and sustainability of these and other crops.

IFPRI

International Food Policy Research Institute 1200 Seventeenth Street, N.W., Washington, DC 20036-3006, USA. Founded 1975. To focus on identifying and analyzing policies for meeting food needs of developing countries, particularly the poorer groups within those countries. Research covers ways to achieve sustainable food production and land use, improve food consumption and income levels of the poor, enhance the links between agriculture and other sectors of the economy, and improve trade and macroeconomic conditions.

IIMI

International Irrigation Management Institute P.O. Box 2075, Colombo, Sri Lanka. Founded 1984. To strengthen the development, dissemination, and adoption of lasting improvements in the performance of irrigated agriculture in developing countries.

IITA

International Institute of Tropical Agriculture PMB 5320, Ibadan, Nigeria. Founded 1967. To contribute to sustainable and increasing food pro-

duction in the humid and subhumid tropics and thereby to improve the well-being of low-income people by conducting international agricultural research and outreach activities in partnership with African national agricultural research systems, particularly on maize, cassava, cowpea, plantain, soybean, and yam.

ILCA¹

International Livestock Centre for Africa

P.O. Box 5689, Addis Ababa, Ethiopia. Founded 1974. To strengthen the ability of national agricultural research systems to conduct technical and policy research in livestock-related fields, to develop technical packages for increasing livestock production and the contribution of livestock to sustainable agricultural production and income, and to contribute to scientific knowledge in a way conducive to solutions to livestock production problems.

ILRAD¹

International Laboratory for Research on Animal Diseases

P.O. Box 30709, Nairobi, Kenya. Founded 1973. To serve as a world center for research on ways and means of conquering, as quickly as possible, major animal diseases (trypanosomiasis and tick-borne diseases) that seriously limit livestock industries in Africa and in many other parts of the world.

INIBAP²

International Network for the Improvement of Banana and Plantain

Parc Scientifique Agropolis-Bât 7, Boulevard de la Lironde, 34980 Montpellier-sur-Lez, France. Founded 1984. To increase the productivity and stability of banana and plantain grown on smallholdings by initiating, encouraging, supporting, conducting, and coordinating research; by strengthening national and regional programs and facilitating the interchange of improved and disease-free genetic material; by coor-

minating and supporting the collection and exchange of documentation and information; and by coordinating and supporting training for researchers and technicians from developing countries.

IPGRI³

International Plant Genetic Resources Institute

Via delle Sette Chiese 142, 00145 Rome, Italy.

Founded 1974. To encourage, support, and engage in activities to strengthen the conservation and use of plant genetic resources worldwide, with special emphasis on developing countries, by undertaking research and training and by providing scientific and technical information.

IRRI

International Rice Research Institute

P.O. Box 933, 1099 Manila, Philippines. Founded

1960. To improve the well-being of present and future generations of rice farmers and consumers, particularly those with low incomes, by generating and disseminating rice-related knowledge and technology of short- and long-term environmental, social, and economic benefit and by helping to enhance national rice research.

ISNAR

International Service for National Agricultural Research

P.O. Box 93375, 2509 AJ The Hague, The Netherlands. Founded 1979. To help developing countries bring about sustained improvements in the performance of their national agricultural research systems and organizations. ISNAR does this by supporting their efforts in institutional development, promoting appropriate policies and funding for agricultural research, developing or adapting improved research management techniques, and generating and disseminating relevant knowledge and information.

WARDA

West Africa Rice Development Association

01 B.P. 2551, Bouake 01, Côte d'Ivoire. Founded 1970. To conduct and promote research to improve the technical and economic options available to smallholder farm families in the upland/inland-swamp continuum, the Sahel, and the mangrove swamp environments by developing improved rice varieties and production methods, by reducing postharvest losses, by assessing and increasing the acceptability and impact of new technology, and by investigating issues affecting technology adoption and analyzing national policy options.

¹The CGIAR decided at its 1993 Mid-Term Meeting to establish a single institution that builds on the strengths of the existing livestock centers, ILCA and ILRAD, and replaces them. The new center will be known as the International Livestock Research Institute (ILRI).

²The CGIAR decided at its 1993 Mid-Term Meeting that banana and plantain research should be carried out by a consortium, including INIBAP, under the governance and administrative structure of IPGRI, in cooperation with IITA.

³Successor to the International Board for Plant Genetic Resources (IBPGR).

The Year in Review



CIP scientists distribute thousands of improved potatoes to developing countries.

The 1994 Mid-Term Meeting of the CGIAR, held May 23–27 in New Delhi, is the cutoff point for this review. At that meeting, the CGIAR confronted a crisis of confidence and emerged with a commitment and a program of action to overcome the crisis. At the heart of the crisis was a significant decline of funding for CGIAR programs since 1992 in both real and nominal terms. The decline continued in 1994 and was expected to persist in 1995 unless a major effort was made to reverse the situation. The CGIAR responded to the funding shortfall by streamlining procedures, curtailing some programs, reducing staff, and merging four centers into two as an initial effort to restructure the system. Some 110 senior international scientist positions and 2,000 locally hired positions were dropped across the system, leaving little excess capacity to shed.

Against this background, CGIAR Chairman Ismail Serageldin convened a consultation in

Washington, D.C., early in 1994 to examine strategic issues that could affect the future viability of the CGIAR. Participants in the consultation reaffirmed the need for the CGIAR to be supported in a manner consistent with its effectiveness as an instrument of development. They agreed that the CGIAR system needed strengthening, financial stability, and a research-driven agenda.

The New Delhi Mid-Term Meeting provided opportunities for the CGIAR to be rededicated as a dynamic institution, driven by the research needs of developing countries and the scientific capacity of the centers but conscious of financial realities. CGIAR members responded fully in all areas, acknowledging that urgent measures are required to stabilize the system's finances, reform its governance and operations, clarify the vision that guides its role and mandate, and renew international support for its mission. They emphasized the need for changes in the

system's governance that would result in predictability, transparency, and accountability. In response to a joint appeal for support to the CGIAR from Lewis Preston (World Bank), Jacques Diouf (Food and Agriculture Organization; FAO), and Gustave Speth (United Nations Development Programme), some members made firm offers of additional funding, thus triggering a one-time-only special contribution from the World Bank (see below).

The CGIAR endorsed the key thrusts of a strategy for revitalizing the system outlined by Mr. Serageldin:

1. Agreement that the system's research agenda must drive the budget, not the other way around.

2. Decisive efforts to stabilize the financial situation and halt erosion of the system's scientific capacity, primarily in two areas:

- a. An effort to mobilize additional resources for the system's approved core program so that, through a matching formula, the CGIAR can fully use the World Bank's offer of a one-time special grant of \$20 million (additional to the customary annual grant) for 1994-95. The Bank's package is linked to a two-pillar strategy: adoption of a reform plan by the CGIAR, and availability of matching funds from other donors. Donor contributions could be either "new" funding or funds redirected from other areas to the core program that was approved at International Centers Week (ICW) 1993.

- b. A revision of funding strategies to focus future donor contributions on the core research program. This effort would require greater discipline by both centers and donors.

3. Formulation and adoption of a new vision for the CGIAR.

4. Refocusing of the research agenda, to reflect the new vision.

5. Reformation of governance and management to ensure predictability, transparency, and accountability.

6. Full integration of developing-country perspectives within the CGIAR policy framework.

7. Linkages of CGIAR programs with others, including participatory programs at the farm level.

8. Agreement on a plan of action and timetable to formulate and endorse details of the



This pasture seed sweeper, developed by ICARDA, is used to determine the pod sowing rate necessary to establish a reasonably dense pasture.

new strategy and principles and secure their ratification at high levels of government.

The 18-month timetable to formulate and endorse details of the new strategy and principles, proposed by Mr. Serageldin and adopted by the CGIAR, follows:

1. At the New Delhi Mid-Term Meeting of the CGIAR (May 1994), develop a shared vision among donors of how to build a more effective system that is funded in a predictable and sustainable fashion.

2. Follow up on the consolidation and elaboration of the proposals adopted (Summer 1994).

3. Formally adopt the proposals to be submitted to donor authorities for their consideration (ICW, October 1994).

4. Invite high-level participation at a special meeting to engage donors in setting future directions for the CGIAR (November 1994).

5. Hold a high-level meeting (late January-early February 1995).

6. Define needed changes and instruments (Spring 1995).

7. Adopt the detailed changes and instruments (Mid-Term Meeting, May 1995).

8. Take action in capitals, and seek formal ratification if needed (Summer 1995).

9. Adopt final new structures, procedures, and programs (ICW, October 1995).

These changes will enable the renewed CGIAR to become effective by January 1996.

The Wisdom of Experience

When Shri P. V. Narasimha Rao, Prime Minister of India, formally inaugurated the 1994 Mid-Term Meeting with an informative and inspiring address, he emphasized the importance of agriculture and the need for action at both the local and global levels to nurture agricultural development. In a special message to national and international scientists, he said:

I would like you to think of the whole world, think of all the variety that God has given to this globe, and at the same time think of the need to find differentiated and properly considered prescriptions for each of those varieties rather than tarring everything with one kind of brush. That is not going to work in agriculture. Every plot of land is like a human being, it has to be tended like a child and that is what we, the farmers, think about our land.

The Prime Minister said it was appropriate that the meeting was being held in India, which was an early user and beneficiary of the international agricultural research system, as well as

“Every plot of land is like a human being, it has to be tended like a child and that is what we, the farmers, think about our land.”

—Indian Prime Minister P. V. Narasimha Rao

a contributor to the strength of the system. The products of CGIAR-funded research, he pointed out, fueled the green revolution that helped to feed and nurture millions. He dismissed the notions that the green revolution is responsible for inequity and that green revolution crop varieties are inherently hostile to the environment.

Globally, he said, cooperation as spearheaded by the CGIAR was a positive approach to the complex issues relating to alleviation of poverty and management of natural resources that lie ahead.

Other speakers at the inauguration included India's Union Minister of Agriculture, Shri Balram Jakhar; Mr. Serageldin; and Professor V. L. Chopra, Director General of the Indian Council of Agricultural Research and a member of the CGIAR Oversight Committee.

Governance and Organization

During the period under review, the 23-year-old CGIAR “model” of governance was modified, and the ground was prepared for further change. These actions came in response to concerns among stakeholders of the system that the existing deliberative and decision-making processes were inadequate to cope with a transformed international environment.

The perceived need for change was articulated through a working group established at the 1992 Mid-Term Meeting (held in Istanbul) under the chairmanship of Mr. Robert Herdt of the Rockefeller Foundation. The working group proposed the appointment of two standing committees (covering finance and evaluation) as a mechanism for a sharply focused examination of key issues leading to recommendations on which the CGIAR as a whole could base its policy decisions.

As a first step toward an overhaul of governance, the CGIAR at its 1993 Mid-Term Meeting (held in San Juan) appointed a Finance Committee consisting of donor representatives and an Oversight Committee of donors serving in their personal capacity. At New Delhi, the CGIAR agreed that as the system rededicates itself to a fully funded core agenda, mechanisms will be required to monitor this process, assisting both donors and centers to impose discipline on themselves. The system's governance would therefore need further review and revision to ensure that decisions are taken in a dynamic manner and consistently implemented across the system.

As the next significant step in the overhaul of governance, a 15-member Steering Committee was established in May 1994 under the leadership of the CGIAR Chairman, to add dynamism to the system's decision-making processes. The Steering Committee will consist of members of the Finance and Oversight Committees, which will also continue to function as separate committees.

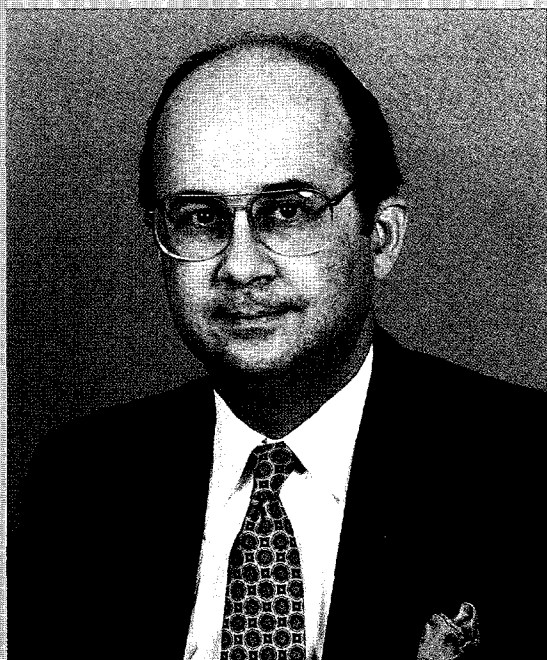
Change of Chairman

Producing more food while conserving the environment and reducing poverty in a framework of sustainable development were listed as key goals by the new Chairman of the CGIAR, Mr. Ismail Serageldin, in his initial (January 1994) message to the Group. The Chairman's gavel changed hands when Mr. V. Rajagopalan, whose tenure as the sixth CGIAR Chairman began in 1991, retired from service at the World Bank on December 31, 1993. Mr. Serageldin, whose nomination as the Group's seventh Chairman by World Bank President Lewis T. Preston was unanimously affirmed at ICW 93, is the Bank's Vice President for Environmentally Sustainable Development.

Mr. Serageldin, an Egyptian national, is an alumnus of Cairo University and of Harvard, where he earned a Ph.D. He joined the Bank in 1972 and during his career has designed and managed a range of poverty-focused projects. He is an internationally published author on economic development, human resource issues, the environment, architecture, the Arab world, Islam, and culture.

His message was: "I am honored to succeed Visvanathan Rajagopalan as Chairman of the CGIAR. The goals of the CGIAR and those of my World Bank vice presidency are complementary. Increasing the world's supply of food is an imperative, but no less important is the need to develop innovative ways of conserving the environment and reducing poverty, both within a sustainable development framework. The CGIAR is an enduring example of a successful development program, built on a solid foundation of cooperation among a large group of donors, farmers, and national research organizations. In retrospect, the CGIAR has made remarkable contributions to the fight against hunger and poverty. In prospect, it is well equipped to address effectively some of the most pressing problems of development and assist in empowering the world's farmers to become more productive while better managing their resources."

The CGIAR adopted a farewell resolution



Mr. Ismail Serageldin

at ICW 93, recording its appreciation of Mr. Rajagopalan's leadership. The resolution read as follows: "Members of the CGIAR extend their felicitations to the Group's sixth Chairman, V. Rajagopalan, as he completes a career of public service dedicated to the cause of development, ends his leadership of the Group, and prepares for retirement. They hereby place on record their appreciation of his wise and dedicated leadership at a critical period in the history of the CGIAR. They are particularly grateful to him for encouraging the CGIAR system to move in new directions, undertake innovations, and face squarely the problems it confronts, while at all times remaining faithful to the Group's original goal of improving the lives of the world's poor. His contribution to the CGIAR system will be remembered with respect and affection."

Responding to the resolution and to individual comments by CGIAR members and representatives of international research centers, Mr. Rajagopalan thanked the speakers for their "kind words" and for their appreciation of what he had tried to do as their Chairman. His efforts, he said, were based on a very simple premise: "The CGIAR is good value for the international community."

“The goal of achieving sustainable food security in the decades ahead emerges as one of the greatest challenges humanity has ever faced. We must see sustainable food security as a fundamental aspect of global human security. The world needs to recognize the right to food as a universal human right.”

—Gustave Speth, Administrator, United Nations Development Programme, at International Centers Week 1993

In broad terms, the Steering Committee's mandate is to help guide the CGIAR through the 18-month transition period it adopted. The Steering Committee will help provide the system with options and guidance on forms of governance, on priorities, on securing commitment by the donors to fund agreed priority programs, on ensuring transparency and accountability in funding arrangements, and on relations with partners in the global research system.

Governance, decision-making, and financing arrangements will be the subject of studies by expert panels from which recommendations will be presented through the Steering Committee to ICW in October 1994.

Financial Strategies

In meeting the challenge posed by financial circumstances, the CGIAR decided that its financial arrangements should be reformed to increase transparency and accountability and bring predictability to the budget. This decision requires that the agreed research agenda and work program, which constitute the CGIAR's mandate, be articulated in a comprehensible fashion and be used as the benchmark against which various activities would be funded and the progress of their implementation monitored.

A matrix approach was adopted as an organizing framework to meet these needs. By plotting programs in relation to centers, this matrix approach explicitly recognizes the ability of each donor to provide its support to an individual center (with freedom to reallocate among activities within that center's work program)

or to individual programs (with freedom to reallocate among centers active in the implementation of that program) or to a specific cell in the matrix (an individual activity in a particular center). The transparency provided by this approach should enable the CGIAR to ensure that no part of the overall research agenda and work program adopted in the matrix remains unfunded and that no individual cell of the matrix is oversubscribed.

For the 1994–95 transition, the currently approved research agenda and work program—recommended by the CGIAR's Technical Advisory Committee (TAC), approved by donors at ICW 93, and costed at \$270 million—would not be put in question, but a new agenda and related budget could be considered for the 1996 program.

Every effort will be made for donors to come to ICW 94 in October with as much clarity as possible about their intentions for funding the 1995 program, so that a definitive budget can be prepared for the centers. The objectives would be that the centers should have their budgets in November, and be in possession of at least 50 percent of that budget before January 1, 1995, with the remaining 50 percent in hand no later than June 1995. It was also recognized that some donors would have to make conditional pledges depending on their parliamentary or other statutory approval procedures, but the pledges would be serious proposals that would have a high probability of being confirmed.

For the transparency of the new system to work, it was agreed that the CGIAR Secretariat had to function as a clearinghouse for all the data about financial agreements and flows between the donors and the centers. The donors agreed to collaborate by reporting promptly all such agreements and transactions so that the Secretariat's reports to the Group could be comprehensive, accurate, and transparent.

Plant Genetic Resources

Plant genetic resources work in the CGIAR system was the subject of a “stripe” or systemwide review, which recommended that, to respond efficiently and effectively to the global demands on genetic resources, “the CGIAR must leap from its paradigm of individual voices at autonomous centers to a fully coordinated policy on

genetic resources management across the system." Arguing, as well, for "greater visibility" of the system's efforts in genetic resources, the report said that "anything less may bring undesirable responses through further funding cuts, reduced access to genetic resources and continued controversy." The review was conducted by an international panel chaired by Mr. Henry L. Shands of the United States.



An example of plant genetic resources, these potato microtubers are distributed by CIP scientists to researchers in developing countries.

In response to the panel's report, the CGIAR reaffirmed the "in trust" status of CGIAR collections, with the understanding that they will be placed under the umbrella of an international agreement. Centers should not seek to benefit financially from the commercialization of germplasm, but should work with national agricultural research systems (NARS) in developing countries at their request, should opportunities for commercialization arise.

The Genetic Resources Units at the centers will be elevated to program status, and the centers will receive separate funding for genetic resources work that will not be exchangeable across their other activities.

The Intercenter Working Group on Genetic Resources (ICWG-GR) will be the CGIAR

steering committee to guide policy and management of genetic resources. IPGRI will be the lead center on genetic resources programs, and the IPGRI Director General will be director of the systemwide Program on Genetic Resources. IPGRI will provide a small secretariat for the ICWG-GR.

The CGIAR endorsed a draft agreement by which its centers that maintain germplasm collections could place them under the auspices of FAO. The purpose of the agreement is to provide an international legal framework for a vigorous, multilateral, plant genetic resources system. The agreement will be entered into after some clarifications sought by CGIAR members have been obtained. The main points on which clarification were sought are the timing of the agreement, the need for clarity on legal commitments, and the question of how to cope with the variety of international conventions that touch on the subject. Clarification will be sought at international meetings that consider the issues and through consultation among cosponsors.

Followup to Agenda 21

As part of the CGIAR's continuing effort to sharpen its response to Agenda 21, produced by the United Nations Conference on Environment and Development, several concept proposals were developed. They are for projects relating to marginal lands; integrated pest management; *in situ* conservation of crop, livestock, fish, and forest genetic resources; and geographical information systems (GIS), such as agroecological data bases. The proposals, prepared by a CGIAR Task Force led by Mr. Stein Bic (Norway), took into account a study on soil, water, and nutrient

"Building farmer and farming systems perspectives into the technology generation process will be crucial for ensuring greater acceptance of technologies. This will require enhanced emphasis on social science research as a component of the research agenda."

—V.L. Chopra, Director General, Indian Council of Agricultural Research, at the 1994 Mid-Term Meeting



Research covering banana and plantain, the fourth major food crop for developing countries (after rice, wheat, and maize), continues to be a priority for the CGIAR.

management conducted by the International Board for Soil Research and Management (IBSRAM). These proposals will be developed further, in consultation with TAC, for implementation by CGIAR centers that are focal points for natural resource management activities.

Livestock Research

Consideration of priorities and strategies for livestock research, which began with the discussion at ICW 92, led to the decision taken at the 1993 Mid-Term Meeting that livestock research should be entrusted to a single institution with global responsibilities for strategic research in genetics, physiology, nutrition, and health. A single, livestock research strategy will incorporate appropriate programs from the existing livestock research centers (ILCA and ILRAD) as well as other centers, such as ISNAR, IFPRI, CIAT, ICARDA, ICRISAT, and ICRAF. The decision was based on recommendations from a working group led by Mr. John "Taff" Davies (United Kingdom) and from TAC. The Rockefeller Foundation agreed to serve as implementing agency for the decision. By mid-1994, arrangements were under way for the new center—the International Livestock Research Institute (ILRI)—to commence work on January 1, 1995.

Banana and Plantain

Research covering banana and plantain, the fourth major food crop for developing countries (after rice, wheat, and maize), continued to be a priority for the CGIAR. It decided that the focus of INIBAP should be on disease-resistant *Musa* germplasm and related documentation, information, and training and that these activities should be carried out by a consortium of institutions including INIBAP under that center's governance and administrative structure. Meanwhile, IITA will continue its crop improvement research. The merger of INIBAP's governance structure with IPGRI was completed in May 1994.

Eastern Europe

At ICW 93, the Oversight Committee was asked to develop a policy for CGIAR relations with Eastern Europe and the newly independent states of the former Soviet Union. A report from the Oversight Committee to the 1994 Mid-Term Meeting suggested that the CGIAR should maintain a restrictive attitude toward the expansion of its activities in these countries. The report recommended that no activities should be carried out in a manner that infringes on the capacities of CGIAR centers to carry out their mandates in the "traditional" developing countries.

Mr. Johan Holmberg (Sweden), presenting the committee's report, said that the suggestion was influenced primarily by the financial situation of the CGIAR. He stressed, however, that the CGIAR should maintain open scientific contact—including the monitoring of scientific developments—with the countries concerned, that the region should be adequately represented in the CGIAR, and that previously approved activities by CGIAR centers in these countries should continue. He raised the possibility, as well, that some countries in the region would want to join the CGIAR.

Following these recommendations, the CGIAR decided to proceed in a prudent manner in expanding activities in the region, to encourage the expansion of scientific and academic contacts, and to invite FAO to arrange for representatives from the region to be included in the representation of Europe in the CGIAR.

The Russian Federation joined the CGIAR in May 1994, to become its 42nd member.

Intellectual Property Rights and CGIAR Research—Predicament or Challenge?

by Wolfgang E. Siebeck

The implications of intellectual property protection for center research and the flow of genetic material were reviewed at ICW 93 by expert panels that included representatives from developing countries, nongovernmental organizations (NGOs), and industry.

The discussion produced diverse viewpoints, ranging from cautioning the centers against adopting a policy of intellectual property protection to urging them to adopt such a policy unambiguously to permit collaboration with private-sector research organizations, and through such collaboration, the transfer of proprietary technology to developing countries.

The decision of whether or not to adopt such a policy is not a straightforward one. A careful assessment is under way.

This panel discussion was the latest evidence of the growing importance that intellectual property issues have acquired within the CGIAR. The issues are complex, and the interests involved are manifold. Intellectual property, primarily in the form of patents and plant breeders' rights, is seen by many as an important, if not critical, incentive to spur breeding advances and genetic recombination that will allow the feeding of a growing world population in a sustainable fashion.

This claim is challenged by many, particularly in developing countries. They fear that individual rights over improvements to their traditional seeds not only deprive farmers of compensation for use of the original material, which often represents selection efforts by generations of farmers, but encroach on the traditionally free use and exchange of seed materials. Although claims on both sides of the argument appear to be overstated, both sides are building a case for restricting the use of the genetic material they control.

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The international agricultural research centers (IARCs) are caught in the middle of these arguments. They are deeply concerned that their access to both unexplored genetic material and technological advances may be foreclosed unless they change their current policy, under which they receive and release genetic material without restrictions and concerns for property rights.

Toward a Policy on Intellectual Property

Intellectual property considerations are not new in the CGIAR. ILRAD, in its research for vaccines against trypanosomiasis (African sleeping sickness) and theileriosis (East Coast fever), filed for a patent at the behest of its private-sector partner, which otherwise was unwilling to provide the funds to develop the vaccine and bring it to the market. IRRI holds patents on small farm machines that it developed. However, the CGIAR centers have not yet been exposed

There is reason to expect that developing countries rich in genetic resources will continue to make these available to the centers for conservation and research, because only the widest exchange of germplasm for food crops of primary concern to them can ensure the genetic improvements necessary to sustain production for an increasing population.

to intellectual property issues in the context of plant genetic resources.

In 1982, the CGIAR started a series of reviews on the implications of intellectual property protection for center research, involving TAC and its center directors. Because this was well before plant patenting became an accepted proposition, these reviews reflect only on the implications of plant breeders' rights for the centers. They have helped the CGIAR to consolidate the legal basis for its germplasm holdings, to establish preliminary principles on intellectual property management, and to set guidelines on how it expects users to handle genetic material distributed by a center.

One of these reviews by TAC concluded that because of the breeders' exemption anchored in the International Convention for the Protection of New Varieties of Plants (UPOV Convention; see below), the centers had no reason to be concerned about possible constraints to be imposed on their access to germplasm. And as centers moved increasingly into strategic research and therefore produced less finished varieties, the problem would lose its relevance.

Upon TAC's recommendation, the CGIAR in 1988 adopted its current policy on plant genetic resources, stating that its centers hold their germplasm collections "in trust" and that they have the duty to distribute germplasm from these collections to any researcher who demonstrates a legitimate interest.

Under this policy, the centers make no attempt to control subsequent commercial uses of such germplasm. By defining the legal basis for holding the collections of genetic material in its genebanks as trusteeship, the CGIAR gave

formal recognition to the arrangements under which the centers had previously received such material into their custody.

In 1989, a report on biotechnology co-sponsored by the World Bank, ISNAR, the Australian Centre for International Agricultural Research (ACIAR), and the Australian International Development Assistance Bureau (AIDAB) suggested that the centers may need to seek patents on their significant discoveries, either to prevent their control by others or to negotiate access to new technologies. Patent ownership would be critical in negotiating collaborative arrangements with private biotechnology companies.

The study also saw a role for international development agencies and for the centers to negotiate access to technology on behalf of small countries or groups of small countries that otherwise would not have access to new technologies.

Three workshops were conducted with outside experts between November 1990 and January 1992. The last two involved a newly created working group of center directors, and a joint TAC/center director committee, both charged with assessing intellectual property issues. Concerns in these discussions encompassed the desire not only to keep genetic material in the public domain, but to protect the interests of suppliers of such material to the centers. All three meetings concluded that in future, the centers should consider distributing germplasm under some forms of material transfer agreements.

At Centers Week in October 1991, the center directors circulated "Suggested Principles for a Future CGIAR Policy on Intellectual Property Rights," in which they affirmed the CGIAR's adherence to the principle of unrestricted availability of its plant genetic resources.

These "Suggested Principles" specified conditions in which the centers would or would not seek intellectual property for themselves (never on "naturally occurring genes" and on other products only exceptionally, to ensure access to technology without seeking financial gain).

At its meeting in Istanbul in May 1992, the CGIAR unanimously adopted a "working document" that was not intended to be a definitive policy statement; rather, it was meant to reflect current policies and practices of the CGIAR centers and to represent broadly held views within

the CGIAR system. It mirrored the "Suggested Principles" issued by the center directors and affirmed the continued free availability of gene-bank material. The minutes of the meeting state that centers and their boards of trustees bear the responsibility for developing particular policies and procedures relating to the implementation of intellectual property management.

The Drive for Control over Plant Breeding And Genetic Resources...

The CGIAR did not deliberate in isolation. On the contrary, its reviews and soul-searching very much reflected changes in attitudes observed in the research community at large.

In the post-World War II years, intellectual property protection was often seen as anticompetitive, threatening the antitrust and free trade policies of the time. By contrast, spurred by the technology race, the 1980s saw a gradual but steady tightening of intellectual property protection in most industrial countries. The view that strong protection of intellectual property could help retain or regain technological leadership gained respectability, particularly in the United States, which to many observers was then losing it to Japan.

Several international initiatives resulted, and among them was a revision in 1991 of the UPOV Convention, which narrowed the previously broad breeder's privilege to use a protected variety for "on-breeding" and a farmer's right to sell his or her harvest as seed.

The most significant initiative was launched as part of the Multilateral Trade Negotiating Round in the General Agreement on Tariffs and Trade (GATT), known as the Uruguay Round, which ended in December 1993. Strengthened protection of intellectual property was included as a key negotiating subject at the insistence of the industrial nations.

At the outset, developing countries were opposed. Eventually they relented because of the trading benefits they expected from other areas of the trade pact and because many are moving toward stronger protection of intellectual property. They agreed to submit to the "Agreement on Trade-Related Intellectual Property Rights" (the TRIPS Code), which goes far beyond what developing countries previously had been ready to accept under international agreements. The

Recent Actions on Intellectual Property Issues Initiated in the CGIAR

Several studies are under way to prepare the CGIAR to define a policy on intellectual property issues.

IPGRI has co-sponsored a study program with nongovernmental organizations that aims to build a consensus among interested parties. The study has been published under the title, "People, Plants and Patents—The Impact of Intellectual Property on Trade, Plants and Biodiversity" by the International Development Research Centre (IDRC) in Ottawa, Canada.

IPGRI also has published a paper, co-funded by the CGIAR Secretariat, on the possible use of material transfer agreements for germplasm acquisition and distribution by the centers. It is entitled, "Material Transfer Agreements in Genetic Resources Exchange—The Case of the International Agricultural Research Centers" (*IPGRI Issues in Genetic Resources*, No. 1).

Individual centers and the CGIAR are increasing their participation in international forums in which issues of intellectual property and access to germplasm are reviewed, such as the FAO Commission on Plant Genetic Resources, and various groups charged with the implementation of the Convention on Biological Diversity and the preparation of its first Conference of the Parties to the Convention. They have also committed their support to the preparation of FAO's Fourth Technical Conference on Plant Genetic Resources, which will prepare a status report on the world's genetic resources and a global plan of action.

To strengthen international solidarity, the CGIAR centers have accepted the invitation of FAO's Director-General to place their collections of genetic material under the auspices of that organization as part of its international network of *ex situ* collections.

TRIPS Code requires countries to protect any invention (process or product) in all fields of technology. They may exempt plants from “patentable subject-matter” but have to protect varieties, through patents or a *sui generis* system. To bring their legislation into compliance, the TRIPS Code grants developing countries a grace period of 5 years, which can be extended by another 5 years, and for least developed countries, by 10 years.

...And Control over Genetic Material

These efforts in UPOV and GATT to broaden the scope of individual control over inventions and advances in breeding technology were paralleled by attempts to regulate internationally the access to, and use of, genetic resources.

In 1983, FAO established the “International Undertaking on Plant Genetic Resources.” This was an attempt, through international conservation efforts, to stop or slow the rapid disappearance of crop plant species resulting from genetic erosion.

The International Undertaking originally subscribed to the rule of free exchange of plant genetic resources, which it recognized as “heritage of mankind.” In subsequent years, however, disagreement over the scope of intellectual property protection—and specifically over whether breeders’ lines and material protected by plant breeders’ rights, under the rule of the Undertaking, should be available without restriction—led to a narrowing of the free-exchange principle. An “agreed interpretation” of 1989 introduced the notion of compensation into the exchange of germplasm. In 1991, the free-flow principle was further qualified when FAO adopted a resolution that recognized the common heritage principle, but subordinated it “to the sovereignty of the states over their plant genetic resources.”

Unlike the International Undertaking, which

To access proprietary knowledge, the centers will have to protect owners’ intellectual property interests; to access genetic resources, they will have to protect the interests of source countries under the Biodiversity Convention.

is a voluntary commitment, the Convention on Biological Diversity of 1992 has the force of an international treaty for nations that have ratified it. While recognizing the intrinsic value of biological diversity of all life forms and the critical importance of conservation and sustainable use of plant genetic resources, the Convention formally recognizes sovereign control by individual nations over biological resources on their territories, and their right to compensation for granting access to these resources.

The Convention excludes genetic material collected before December 29, 1993, when the Convention took effect (even if that material is stored in an international center within the territory of the country of origin). In a country that has become a party to the Convention, material collected on or after that date will be subject to the provisions of the Convention.

Choices for the Centers

Traditionally, the international centers enjoyed free access to the knowledge pool of agro-genetic research worldwide, as well as to the global genepool. Drawing on both is, in fact, the key to their mission, and their past success.

The future may be more complex. To access proprietary knowledge, the centers will have to protect owners’ intellectual property interests; to access genetic resources, they will have to protect the interests of source countries under the Biodiversity Convention.

This is not to suggest that the centers will have to pay in each case. There is reason to expect that proprietary technologies can be tapped for use in developing countries at no or nominal royalties, as long as an owner can amortize research and development expenses in protected industrial-country markets. There is also reason to expect that developing countries rich in genetic resources will continue to make these available to the centers for conservation and research, because only the widest exchange of germplasm for food crops of primary concern to them can ensure the genetic improvements necessary to sustain production for an increasing population.

For the CGIAR centers, these changes may require new strategies for interacting with suppliers of both knowledge and genetic material. They may also require carefully crafted arrangements that represent an equitable business deal.

Current Research Efforts of the CGIAR



*New upland rice plant types that are more competitive with weeds have been created by WARDA breeders through wide crosses between traditional African *Oryza glaberrima* and Asian *O. sativa* parents.*

Modern agriculture is an enterprise that evolves continuously, based on new knowledge derived from research. As the world reaches out for a better understanding of the complex interactions among physical, biological, and social systems, research can enable the international community to construct a new agricultural regime that is global, development-oriented, equitable, and sustainable. The international agricultural research centers of the CGIAR system are centers of excellence that create new knowledge and generate new technologies. A critical mass of more than 1,000 skilled scientists, drawn from many nationalities, carries out these activities. The “public good” nature of their research makes it accessible to all. No comparable group of scientists works solely for the benefit of developing countries, uninhibited by politics, and involved equally with the summits of scientific endeavor and with the grassroots of farm activity. This summary report provides a flavor of research in progress at the CGIAR centers, indicating how these efforts will affect agriculture in developing countries and demonstrating their potential impact on the lives of the poor. There is such a range of research to be reported that only an illustrative selection can be presented here.

CROP PRODUCTIVITY RESEARCH

Research to increase foodcrop productivity—and maintain the levels already achieved—remains the foremost goal of the CGIAR centers. With almost 100 million more consumers in the developing world each year, food output must double over the next 20 years. Making plants more efficient in using light, nutrients, water, and temperature means maintaining or increasing yields in a sustainable manner while lowering the levels of these production inputs. Current activities at IRRI, CIMMYT, IITA, and ICRISAT show how classical plant breeding and modern biotechnology combine to push the yield frontier and create the potential for future productivity gains in the farmers' fields.



Farmers inspecting their wheat fields near Bhairahawa, Nepal. Their experiences with growing rice and wheat in rotation provide clues to understanding sustainability problems in this important cropping system.

New Plant Type for Irrigated Rice (IRRI)

The yield frontier for irrigated rice has been stagnant at 10 tons per hectare since the first modern rice varieties were released. In the early decades of the green revolution, there was a substantial gap between the technological potential and farm-level yields.

Today the exploitable gap is small, making it necessary to increase yield in order to raise farm-level productivity. The ultimate target is an irrigated rice plant that raises the yield potential by 50 percent from 10 to 15 tons per hectare in the tropics.

The first generation of the new plant type was scientifically designed in 1989, and today experimental lines with a target of 12 tons per hectare are being evaluated in the field. This rice plant will be released to NARS by 1998. Other generations will follow to reach the ultimate target of 15 tons per hectare. This new plant type will allow Asia to meet the 50 percent increase in rice demand that is projected by the year 2030.

Tropical Hybrid Rice (IRRI)

The widespread development and adoption of hybrids increased rice production in China by 20 percent. The transfer of Chinese hybrids to tropical Asia, however, has been constrained by their susceptibility to diseases. IRRI has made a breakthrough in the development of tropical hybrids that, at current input levels, give 15–25 percent higher yield than the earlier modern varieties.

India and Vietnam released IRRI hybrids in 1993; other countries in Asia, with well-developed seed production infrastructure, are expected to follow soon. A new generation of hybrids based on the IRRI plant type is targeted to increase yields by 30–40 percent over current varieties. They will be available in 8–10 years.

Higher Yielding Wheats (CIMMYT)

New wheat varieties developed jointly by Chinese and CIMMYT breeders yield 10 percent more than the best existing varieties. These cultivars are now moving into farmers' fields in a wheat region covering 7.5 million hectares along the Yangtze River. When fully adopted, they will provide Chinese farmers with some \$450 million each year in additional output.



This farmer in Akufu, Nigeria, is pleased with her harvest of IITA-improved cassava, a high-yielding variety resistant to the cassava green mite.

Improved Varieties of Cassava (IITA)

Ghana released three IITA-improved cassava varieties in 1993, after a five-year, \$1.5 million adaptive research program. Yielding 26–36 metric tons per hectare on farm, they outperform the local varieties by more than 200 percent. Cassava is a main food staple in Ghana, with 1992 production (of unimproved local varieties) estimated at 4 million metric tons. Commercial interest in processing cassava as livestock feed has been constrained by inadequate supplies of improved planting materials and insufficient production equipment. These varieties can help overcome the first constraint. IITA is addressing the second constraint by promoting its cassava-processing equipment for Ghanaian farmers with a \$100,000 grant.

Pigeonpea Hybrids (ICRISAT)

Pigeonpea provides vital protein for large populations of the poor, many of whom are vegetarians, in the semiarid tropics of Asia, Africa, and

the Caribbean. With the discovery of cytoplasmic male sterility, hybrids can have a 40 percent yield advantage over conventional varieties. It will allow production of cheaper hybrid seed, which will encourage more active private-sector participation and enhance farmer adoption and use. By 2002, the impact of hybrids should be evident in better nutrition and improved health for millions of poor people.

CROP BIOTIC STRESS RESEARCH

CGIAR research strives to strengthen plants against biotic and abiotic stresses. Resistance to biotic stresses such as pests, diseases, and weeds reduces or eliminates the need for chemical plant protection with its implied health and pollution hazards. Increasingly, research against biotic stress is needed to maintain rather than raise yield levels already achieved. New pests and diseases appear; others become resistant to chemical plant protection or overcome host plant resistance. The higher the yield levels achieved, the larger must be the annual investment in research to maintain yields. All crop research centers of the CGIAR are active in this sector, which is of vital importance to the sustainability of foodcrop production.

PEST AND DISEASE RESEARCH

Return of the Irish Potato Blight (CIP)

A new form of the late blight fungus—the pathogen responsible for the Irish potato famine of the 1840s—poses a major threat to potato farmers in both developing and industrial countries. The new disease population is far more damaging and aggressive than the pathogen responsible for the infamous Irish famine and will greatly increase the need for stronger and more frequent fungicide sprays.

CIP is organizing an emergency breeding program that will exploit resistance genes found in wild potato species from the center's potato genebank, the largest in the world. CIP pathologists and plant breeders believe that late blight-resistant cultivars could be available in three to five years. Previous CIP research and extension efforts using moderately late blight-resistant



CIAT/Mauricio Amorveza

Dr. Anthony Bellotti, CIAT cassava entomologist, prepares a "green milkshake," a cheap homemade pesticide. Farmers use it to control hornworms on 34,000 hectares of cassava.

varieties provided an annual internal rate of return exceeding 90 percent. In Central Africa, the center's investment of just \$5.6 million is providing annual returns of \$10 million.

Biological Control of Cassava Pests (IITA, CIAT)

The green spider mite attacks some 2.9 million hectares of cassava annually in 35 African countries. Yearly production losses are \$640 million. African farmers will benefit by about \$690 million over 35 years through an international biological control project spearheaded by IITA, with CIAT and Brazilian collaboration.

Scientists have found 12 predatory mites, known as phytoseiids, that help protect cassava fields from the green spider mite. Two species of these phytoseiids have been established in Africa, where they are expected to aid in the control of spider mites. Scientists estimate that within 10 years the new predators can protect

at least 25 percent of the area now affected by the spider mite in Africa, increasing cassava production by about \$145 million annually.

Integrated Pest Management of Potato Tuber Moth (CIP)

In developing countries, the estimated \$300 million spent annually on potato insecticides could rise threefold by the turn of the century. For the past two decades, CIP has led a global effort to develop techniques to control pests without chemicals. Among these are friendly fungi and natural predators, as well as potato cultivars with natural resistance to pests, such as a potato plant with hairy leaves that traps and kills insects. When combined in package form according to local farming conditions, a process known as "integrated pest management" (IPM), these technologies can reduce or eliminate most insecticide sprays. During the next five years, CIP plans to move its collective research on IPM "downstream" to farmers and extension workers in developing countries.

Reducing Pesticide Use in the Andes (CIP)

In recent years, the stability of the Andean eco-region's potato crop has been threatened by an infestation of Andean potato weevils, which routinely damage 50 percent of a farmer's crop. The problem is further complicated by the widespread use of hazardous and largely ineffective insecticide sprays.

In response, CIP has developed practices that control weevils without chemicals. After four years of testing in farmers' fields, damage has fallen to just 4–5 percent. Farmers who use the new practices have an average production increase of 3 tons per hectare—equivalent to \$600 in additional income (per capita income in the Andes is \$300). CIP scientists estimate that IPM pilot research and extension projects on Andean potato weevils are generating a return of 58 percent on investment.

Integrated Pest Management in Sub-Saharan Africa (IITA)

IITA is developing farmer-level integrated pest management for Sub-Saharan Africa's main staple food crops: maize (stem borers and the larger grain borer), cassava (green spider mite,

and several diseases), and plantain and banana (insects, nematodes, and several diseases). The total pest and disease load reduces potential yields by about 50 percent. With an investment of about \$30 million over four years, projects will generate environmentally sound IPM campaigns, through research on pest status, host-pest interactions, biological and chemical control, and improved farming practices. Within three to six years, the results will enable national programs to provide technologies to farmers regionwide.



One of the best ways to encourage nonchemical pest control is for farmers to teach one another. In the high Andes, participating farmers have increased profits by up to \$1,000 per hectare using CIP's integrated pest management practices for controlling potato weevils.

Rice Crop Improvement (IRRI)

Incorporating new genetic diversity for pest resistance into improved plant lines has ensured approximately one-third of current yields without extra chemical pest control. Without continuous crop improvement by IRRI, yields of the original high-yielding varieties such as IR8 would have declined an average 1.3 percent a year (about 2 tons per hectare). In the past four years, more than 60 varieties have been released in 20 countries, bringing the total area of rice production with improved cultivars to more than

50 percent of rice production worldwide. In development are cultivars better adapted to the variable rainfed and upland rice ecosystems that account for more than half of rice area, and cultivars with enhanced resistance to pests, with mechanisms to extend the useful life of new varieties in the field.

Minimizing Use of Insecticides for Rice (IRRI)

Indiscriminate insecticide use has well-known health and environmental consequences. IRRI studies indicate that insecticides can account for more than 20 percent of rice production costs in Asia. IRRI has been working to reduce insecticide use by incorporating genes for insect and disease resistance and enhancing natural biological control agents. All the modern varieties released since the early 1980s have had such resistance. These varieties, along with naturally occurring predator populations, can reduce insecticide requirements for rice production by 80 percent. In most Asian countries, rice IPM can reduce insecticide use by 60–75 percent. Experience with rice pesticides can also have significant spillover benefits for other crops.

Rice-Based, Sustainable Cropping Systems (WARDA)

Since 1970, regional consumption of rice in West Africa has grown by 5.5 percent per year. Although annual production rates also have increased (4 percent), rice imports have outstripped them at a 6.8 percent annual growth rate, for a total cost of nearly \$600 million per year. WARDA is developing rice-based cropping systems with two related goals: to stabilize fragile upland ecosystems, where resource-poor farmers are intensifying cropping yet cannot afford the inputs needed to maintain the land's productivity; and to permit intensified use of the sturdier lowlands, which are better adapted to continuous cultivation, and thereby decrease pressure on degraded uplands.

These systems have potential for application to approximately 1.05 million hectares. Technology options include low-cost water, soil fertility, weed management, and other practices that conserve the existing natural enemies of rice insect pests.



Downy mildew is the most devastating disease of pearl millet. ICRISAT's collaborative efforts to map resistance genes have demonstrated ways to enhance the stability of resistant cultivars.

International Musa Breeding Consortium (INIBAP)

To accelerate the production of new hybrids, banana and plantain breeders across the globe will be linked not only to each other but to biotechnology institutes. The *Musa* consortium aims to develop disease-resistant material that will diminish the use of harmful pesticides and significantly improve productivity on small and medium-size holdings. This effort will have a major impact in reducing poverty and contributing to food security in some of the most vulnerable areas in Asia, Africa, and Latin America and the Caribbean. Three disease-resistant hybrids have been released internationally and are being distributed to farmers.

Black Sigatoka-Resistant Plantain Hybrids (IITA)

Black sigatoka is a devastating fungal disease of plantain and banana that was introduced to Africa about 20 years ago. With a research investment of \$2 million, IITA has developed hybrid plantains that are highly resistant to the disease and have more than twice the yield of existing varieties. IITA-assisted trials in 12 Sub-Saharan countries should produce varieties for release to farmers by 1996. The benefit to farm-

ers who will produce resistant hybrids, a sustainable technology, as opposed to existing varieties that require fungicides, is estimated at 10:1. Annual production with improved varieties could increase from \$2.8 billion to \$6 billion.

Sex Pheromones to Control Pearl Millet Stem Borer (ICRISAT)

The pearl millet stem borer causes annual yield losses of grain and stover estimated at \$100 million in Sahelian West Africa. The recommended control practice is to destroy crop residues that farmers need for firewood, animal feed, and fencing. Seasonal and carryover borer populations could be reduced by use of sex pheromones, which are pest-specific, nontoxic, free of residue, and environmentally safe. Major borer pheromone components have been identified, and locally made cheap traps are available. Development and evaluation will involve farmer-participatory research to enhance the probability of adoption by national programs and farmers within five years.

Gene Markers for Resistance to Downy Mildew (ICRISAT)

Downy mildew is the most important disease constraining pearl millet production. ICRISAT's collaborative research has developed a molecular marker-based genetic linkage map of pearl millet and used it to identify markers for gene blocks that confer resistance to downy mildew in germplasm from India, Niger, Nigeria, and Senegal. Within three years, markers for additional resistance sources will be identified and marker-assisted back-crossing used to transfer resistance into economically important hybrid female parents that lack adequate disease resistance. Research will increase staple food production and productivity for millions of poor in the harshest environments of Asia and Africa.

Chickpea *Ascochyta* Blight Control (ICRISAT, ICARDA)

Ascochyta rabiei causes a major disease of chickpea in northwestern India, Pakistan, West Asia, North Africa, and southern Europe. In epiphytotic years, losses can reach 40 percent. A joint ICRISAT/ICARDA program has developed high-yielding lines with resistance to the

highly variable pathogen. Winter-sown crops yield 50–100 percent more than spring-sown crops; 50 cultivars released in 19 countries have helped stabilize production and made winter sowing possible in the Mediterranean region, where it has been adopted on about 100,000 hectares. Adoption in all potential areas in the Mediterranean alone would result in annual benefits of about \$500 million.

Wilt-Resistant Pigeonpea Varieties (ICRISAT)

Wilt disease, a fungal pathogen, accounts for pigeonpea yield losses of about \$77 million per year. Resource-poor pigeonpea farmers in India, Nepal, and eastern Africa can afford only marginal production inputs; they need resistant varieties. ICRISAT has identified resistance in germplasm and bred a range of genotypes suitable for most cropping systems that include pigeonpea at risk to wilt disease. Four varieties have been released. Maruti is now grown on 0.4 million hectares in India; less than five years after its release, ICP 9145 is now grown on 20 percent of Malawi's pigeonpea area. As resistant varieties spread, they prevent crop losses and provide vital protein for the mainly vegetarian populations of the semiarid tropics.

WEED CONTROL RESEARCH

***Orobanche* (ICARDA)**

Orobanche, a destructive parasitic weed of faba bean, was reduced in on-farm trials on naturally infested fields in Beheira governorate of Egypt by 70 percent—increasing yields by 87.5 percent—by the use of resistant varieties. When resistant varieties were combined with foliar applications of NPK fertilizer and a lower rate of selective herbicide, the yields increased fivefold compared with the local variety and practices. These studies were carried out in ICARDA's Nile Valley Program.

Progress Against *Striga* in Africa (IITA)

A comprehensive research approach has yielded promising results against the threat of *Striga*, a parasitic weed estimated to cause \$3 billion worth of damage annually to sorghum, maize, cowpea, and other crops in savanna areas across

Africa. *Striga* curtails the staple food supply of more than 100 million people in over 40 Sub-Saharan countries, causing crop losses of up to 100 percent in affected fields. With annual funding of about \$1.5 million, IITA's program of integrated *Striga* control in Africa aims at achieving 90 percent control within 8–10 years. Already, resistant IITA maize and cowpea varieties are available to farmers through Nigerian seed suppliers, as well as soybean varieties that show promise as a trap crop or false host. Treatment of maize and cowpea seed with herbicide and transplanting of sorghum seedlings are low-cost technologies being tested. Because *Striga* proliferates as land use intensifies and soils become exhausted, new solutions include measures to promote sustainable agriculture, such as intercropping with nitrogen-fixing legumes. IITA is working on *Striga* resistance in maize with CIMMYT and in sorghum with ICRISAT. National programs in 24 Sub-Saharan African countries have requested resistant IITA maize lines for adaptive testing.

CROP ABIOTIC STRESS RESEARCH

Because abiotic stress limits the yield potential of a crop, it is important to strengthen plants against stresses such as heat or cold; drought or flooding; ultraviolet radiation; soil acidity, alkalinity, salinity, or mineral toxicity. Mineral fertilizer, for instance, can damage a cereal crop if soil moisture is insufficient. Enabling plants to cope better with abiotic stresses also enlarges their area of cultivation, and thus leads to increased food production, higher farmer incomes, and environmental benefits.

CROPS FOR ACID SOILS

Acid-Tolerant Maize (CIMMYT)

Acid soils limit maize production on about 8 million hectares worldwide. CIMMYT has developed new maize varieties that yield as much as 30 percent more in these environments than existing cultivars; they also reduce the need to raise soil pH by applying lime. These varieties are now being tested and adapted to local production conditions by national research programs in Latin America, Asia, and Africa, and should

New CIMMYT-Bred Maize Can Feed 50 Million More People Worldwide: Hardy Cultivars Tolerate Drought and Acid Soil

CIMMYT's researchers have created hardy new breeds of tropical maize (also known as corn) that can boost harvests by 40 percent in the tough environments of the developing world. The new varieties were developed to overcome two typical growing constraints in the tropics: periodic droughts and highly acidic soils.

The new breeds of maize, if planted widely, could feed an additional 50 million people yearly, says CIMMYT, which conducts research in more than 100 countries. They will also help the environment by allowing farmers in the developing world to stay on what were becoming nonproductive lands, thereby saving virgin rain forests and other fragile tropical lands.

Maize is native to the Western Hemisphere, but has become one of the most important crops in both the developed and the developing world. Of the 129 million hectares planted in maize worldwide, some 60.7 million hectares—an area about the size of Texas—are in the tropics and subtropics, mostly in developing countries.



CIMMYT breeder pollinating hybrid maize.

Six acid-tolerant maize varieties were developed in collaboration with the governments of Colombia, Brazil, Peru, Venezuela, and Indonesia. The specially bred maize varieties improve yields by one-half ton per hectare—an increase of 40 percent.

“Development of genetically acid soil-tolerant maize varieties offers an ecologically clean, energy-conserving, and cost-effective way to increase maize yields in these areas,” says Ismail Serageldin, Chairman of the CGIAR. “It would permit sustainable maize cropping systems to be established on acidic savanna and reduce the pressure to farm marginal forest and hillside lands. All of this would help reduce deterioration of fragile agricultural lands and ease the pressure to cut down tropical rain forests to obtain additional farmland.”

“Maize grows marvelously in the temperate climates of North America and Western Europe, producing an average of 7 tons per hectare, compared with an average of just 2.5 tons per hectare for farmers in the developing world,” according to Gregory Edmeades, head of CIMMYT's Maize Sub-Program in Mexico. “But even that 2.5-ton average conceals the true circumstances faced by many farmers in the developing world, who often get considerably less yield because of periodic droughts and because of the widespread incidence of highly acidic soils in the tropics.”

One-half of the 60 million hectares planted in maize in the developing world are subject to periodic drought. Some 13 million hectares are located in Latin America, 7 million hectares in Africa, and 8 million hectares in Asia. Drought caused the loss of an estimated 24 million tons of maize in 1993 in the developing world, an amount representing 15 percent of the potential crop.

More than 40 percent of the world's tropical land is classified as acidic—a total of more than 1.66 billion hectares in 48 developing countries. Nearly 8 million hectares of maize

are planted in acidic soils: 3 million hectares in South America; 2.5 million hectares in Asia; 1.5 million hectares in Africa; and about 1 million hectares in Mexico, Central America, and the Caribbean.

In tropical South America, more than 80 percent of the area used for agriculture has soils with acid characteristics. The area under savanna vegetation in Brazil occupies some 180 million hectares, or about 20 percent of the total area of the country. Nearly half of the land in Africa is covered by acid soils in countries like Côte d'Ivoire, Zambia, and Zaire. In East Africa, Uganda, Zimbabwe, and Tanzania have sizable areas under acidic soils. Asian nations with soil acidity problems include Indonesia, Thailand, Malaysia, India, China, and the Philippines.

Drought-Resistant Maize

To develop a drought-resistant maize, the CIMMYT researchers began selective breeding with the *Tuxpeño* variety that was already well adapted to tropical lowlands. They bred this drought-tolerant *Tuxpeño* corn under drought conditions, selecting at flowering the plants with silks that appeared soon after the male flower emerged. When tassel and silk development most nearly coincided, grain production was highest. The selected plants were then bred further over an eight-year period for even greater drought tolerance.

Scientists found that such plants allocate more carbohydrates, or energy, to the ear, which allows them to produce more grain with less moisture. This selective breeding led to the *Tuxpeño Sequia* variety and others like it, which can be grown under a wide range of tropical conditions. "We cannot predict droughts, so we must develop a maize that grows well in both drought and non-drought conditions," says CGIAR Chairman Serageldin. "The new breeds also show up to 10 percent increase in yield during non-drought seasons."

The experiments were carried out in the cool, virtually rain-free winter crop season near CIMMYT headquarters in Mexico, where the timing and intensity of stress were

managed by irrigation. Each of 250 maize lines was grown in single-row plots under three degrees of increasing drought conditions: well watered; intermediate stress, where water was withdrawn during late flowering and throughout grain filling; and severe stress, where no water was applied beginning approximately three weeks before the silks were due to emerge.

The research has already produced new varieties that, in times of severe midseason droughts, produce 2.8 tons per hectare, a 40 percent increase over regular maize yields under similar drought conditions. The improved varieties have now been sent for further field testing to 22 countries that suffer periodic droughts. CIMMYT believes that as many as 20 developing countries in the next 10 years can begin full-scale production.

"Drought tolerance research in maize is producing ever more water-efficient plants, which is another way of saying we're now getting more grain production with less water," says Edmeades. "For that reason, we believe this work—which is aimed at helping desperately poor maize farmers—is wholly consistent with the world community's broader concerns about a better use of environmental resources."

Maize for Acidic Soils

For the past 10 years, CIMMYT researchers have selected several hundred varieties from a wide array of international maize germplasm, which they evaluated under a range of acid soil conditions in Colombia, Brazil, Peru, Venezuela, and Indonesia. In addition, one set of all varieties was also grown on normal soils in Colombia to ensure high productivity under conditions of relatively normal fertility.

"As with maize varieties we've developed for drought, the new maize breeds for acidic soils also increase yields in land that has no acidity problem, which we call 'nonstress environments,'" says Charles Wedderburn, Associate Director of CIMMYT's Maize Program. "In other words, tolerance to soil acidity does not necessarily mean lower performance under high-management conditions."

be available within the next five years. Their widespread use will provide farmers some \$150 million in additional grain and reduced production costs.

Help for Rain Forests from Savanna Upland Rice (CIAT)

New high-yielding rice varieties developed by CIAT and Brazilian scientists can help Latin American farmers protect the Amazonian rain forests. The only crop to tolerate acid soils, the new rices are opening up savannas—traditionally used for pastures—to crop cultivation. To protect the fragile savanna soils from continuous monocropping, farmers interplant the rices with improved pastures, which enrich the soil and increase beef production. With increased incomes, improved soils, and healthier cattle, farmers are less inclined to clear nearby rain forests to create more pasture or cropland. Already more than 6,000 hectares have been planted to this rice-pasture system.

Improved Yield for Mangrove Swamp Rice (WARDA)

WARDA has created a network to speed the transfer and adoption of improved mangrove swamp rice cultivars to national programs. On-farm trials in Sierra Leone, Guinea, Nigeria, Senegal, and The Gambia show that the best-performing cultivars outyielded local varieties under low-input management by an average of 35 percent, and adoption rates are increasing rapidly. In surveyed regions of Sierra Leone alone, from 1986 (when widespread adoption began) to 1990, improved varieties accounted for more than \$14 million in farm-level benefits. Continued diffusion of these varieties, which have moderate resistance to salinity and acidity, will help boost productivity in a potential area of 150,000 hectares—75 percent of mangrove swamp rice area in West Africa.

DROUGHT-RESISTANT CROPS

Groundnut (ICRISAT)

The semiarid tropics are responsible for 70 percent of global groundnut production. ICRISAT research has identified plant types and traits that permit increased production in these drought-



Cultivating groundnut in Vietnam, where ICRISAT is collaborating with the national program through the Cereals and Legumes Asia Network (CLAN).

prone environments. In collaboration with NARS, ICRISAT is testing desirable genotypes in several countries in Africa and Asia; useful traits are being incorporated in breeding programs targeted to drought environments. These efforts are expected to expand among national programs. Varieties with yield advantages for drought-prone environments should be available by the year 2000. ICRISAT estimates a benefit/cost ratio of 5:1 for future research.

Maize (CIMMYT)

Maize farmers in lowland tropical environments lose about 9 million tons of grain each year to drought. CIMMYT has developed new maize varieties that yield at least 25 percent more grain than existing cultivars when drought hits in midseason. These varieties, now being tested by national research programs, should be ready for farmers in three to five years. When fully deployed, they will provide more than \$100 million in additional annual income.

Chickpea (ICRISAT)

Chickpea crops throughout the world face end-of-season drought stress because they grow on stored soil moisture. ICRISAT has developed shorter-duration cultivars that mature before the soil moisture is exhausted. Such cultivars are beginning to be grown on farmers' fields in

peninsular India. Studies have identified traits that contribute to drought resistance, and genotypes with these traits are being used in crossing programs. Expansion of these activities to NARS is expected through networking and working groups within 10 years. The estimated benefit/cost ratio (based only on future costs) is very high, at 114:1.

Upland Rice (WARDA)

WARDA is working to select and diffuse higher yielding, short-duration upland rice varieties. Thousands of improved and traditional varieties of rice from Africa, Latin America, and Asia have been screened to find sources with resistance to blast disease (which has implications for rice cultivation in the United States) for cultivation under improved management in West Africa. The potential area for extending this technology is 446,000 hectares, or about 25 percent of upland rice-growing areas in the West African region. In a wide-crossing program, hybrids have been developed that show improved seedling vigor, weed competitiveness, and excellent grain quality. For upland rice varieties that display better resistance to drought and higher and more stable yields under low-input management, WARDA has targeted a potential region of 1.3 million hectares, or 75 percent of upland rice-growing areas in West Africa.

COLD TOLERANCE

Improved Sorghum (ICRISAT)

Sorghum is a staple cereal crop in the cool tropical highlands of eastern Africa, Lesotho, Yemen, and Mexico. Late-maturing landraces are susceptible to leaf diseases and have poor-quality grain. In 1996, multisite and on-farm testing with NARS will begin for ICRISAT-developed sorghums. Improved cold-tolerant cultivars should reach farmers by 1998; 45 percent adoption is expected to extend sorghum production in Kenya and Mexico and double yields. Farmers will sell surplus grain, thereby increasing family incomes; better-quality grain will improve health of rural farmers and urban poor; and increased fodder production will benefit local livestock.

Chickpea Grown in Subtropical Winters (ICRISAT)

Chickpea grown through subtropical winters produces pods late, and thus exposes the crop to a plethora of end-of-season stresses, including drought, heat, foliar diseases, and pod borers. Plants that begin podding at low temperatures and thus mature earlier could avoid such problems; however, low temperatures can reduce pod set in these farming systems.

ICRISAT has identified sources of cold tolerance and is combining them with other desirable plant characteristics. Widespread use of cold-tolerant chickpeas is expected in target areas by 2005. Benefits include enhanced nutrition of urban and rural poor, and the valuable contribution of legumes to the sustainability of the cropping systems in which they are grown.

Rice in the Sahel (WARDA)

In the Sahel, the challenges of saline and alkaline soils are compounded by extreme temperatures, which contribute to high yield instability and constrain double cropping.

To deal with these problems, WARDA is working to select high-yielding irrigated rice varieties that are tolerant to cold and salinity for the main growing season and dry season planting in the Sahel. These new varieties will be suitable for an area of 75,000 hectares, or 60 percent of cultivated irrigated areas in the Sahel. WARDA also has developed physiological simulation models, which have helped rice breeders improve their cropping calendars and thus reduce their losses.

GLOBAL WARMING

Methane Emissions and Rice (IRRI)

Flooded rice fields, a major source of the greenhouse gas methane, are estimated to contribute 20–35 percent of the world's methane emissions. With partial support from the U.S. Environmental Protection Agency, IRRI began a research program to assess methane emissions from rice fields. Studies indicate that some agronomic practices can be modified to increase yield and reduce methane emissions. They also show that there is no significant effect of a 20 percent increase of ultraviolet-B light on rice yields.

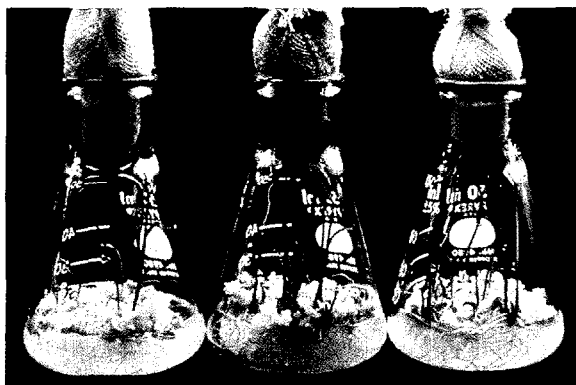
CROP BIOTECHNOLOGY RESEARCH

Although traditional plant and animal breeding remains the principal methodology of plant and animal improvement, CGIAR centers increasingly are using biotechnology to expand the range of their improvement work and accelerate its pace.

A New Tool for Rice Research (IRRI)

Rice, the world's most important food source, has been the target of a large investment in biotechnology. This new tool is being used to increase resistance to pests and diseases, tolerance to adverse soils and climatic conditions, efficiency of nutrient use, and yield potential. Anther culture was used to develop tolerance to cold in Korea and Nepal in 1986 and tolerance to salinity in Egypt in 1992. Wide hybridization among wild rice species has introduced novel genes into high-yield cultivars for resistance to brown planthopper in Vietnam (1992), white-backed planthopper (1993), bacterial blight (1993), and blast (1993). It has also produced a novel cytoplasmic male sterility for hybrid rice (1993).

Wide hybridization continues for resistance to tungro virus disease (1995), sheath blight (1997), and yellow stemborer (1997). In IRRI's breeding program, molecular markers are helping to reduce development time for improved cultivars by 20–30 percent and to double the life of a variety in the field through more durable resistance to blast (1994), bacterial blight (1994), gall midge (1996), and tungro virus



Transferring genetic characteristics through biotechnology.

(1996) and to develop thermosensitive genetic male sterility for hybrid rice (1996). Genes outside the rice family are being used in resistance to yellow stemborer (1996) and sheath blight (1997) and tolerance to salinity (1997).

In developing countries, the release of improved cultivars for pest and disease resistance will yield health, financial, and environmental benefits through reduced use of agrochemicals, more stable yields, and greater profitability. Additionally, cultivars that tolerate adverse environments will permit reclamation of degraded agricultural lands and use of marginal lands, and production of rice hybrids will increase yield.

LIVESTOCK RESEARCH

Livestock, an essential part of the farm economy, is an important sector of CGIAR activity. Research aims at enhancing the sustainability and profitability of smallholder agriculture and improving nutrition and soil fertility. Better livestock management and improved disease control are the mandate of ILCA and ILRAD, which are soon to be joined in a single CGIAR livestock research center with a global mandate, the International Livestock Research Institute.

Higher Incomes, Lower Stocking Rates (ILCA)

Developed by a consortium of institutions (including ICRISAT and ILCA), the broadbed maker shapes the land into broadbeds and furrows that help improve drainage on vertisols. The broadbed maker, like the traditional plough, typically is pulled by oxen. Oxen work only six to seven weeks per year but need to be fed the year-round. A follower herd of 8–10 cattle is needed to ensure regular supply of 2 good draft animals. On-station research by Ethiopian and ILCA scientists has shown that crossbred dairy cows, if adequately fed, can provide farm power for cultivation while producing almost as much milk as nonworking cows (1,200–1,500 liters per lactation).

Simulation of production parameters and investment returns for a 10-year period, using a bioeconomic model, indicates that the value of work output offsets the greater feed costs for



With better fed and managed animals, African smallholders can cultivate more land earlier in the cropping season and so produce more food.

crossbred cows, some reductions in milk production, and longer calving intervals. The technology is being tested on farm in the Ethiopian highlands, which support 24 million cattle (80 percent of Ethiopia's total cattle population). A preintroduction anthropological survey found considerable interest in areas where dairying is profitable and livestock production is intensifying. The farm-level potential of dual-purpose crossbred cows is evidenced by an estimated internal rate of return of more than 100 percent. Potential beneficiaries are smallholder dairy farmers (higher incomes), urban consumers (more dairy products), and the environment (reduction of stocking rates).

Resistance to Endoparasites in Small Ruminants (ILCA)

According to World Bank predictions, small ruminants will have to satisfy 50 percent of Sub-Saharan Africa's meat requirements by 2025. Helminthiasis, a disease of parasitic worms, is the single most important health constraint to improved productivity of small ruminants. In Sub-Saharan Africa alone, estimated direct and indirect losses from ruminant helminthiasis are some \$2 million per year.

Total mortality of sheep in Ethiopia is 10 percent annually; helminthiasis accounts for 20 percent of that loss. Treatment with anthelmintics can lead to a 15 percent (1 kilogram) increase in weight gain annually and can increase the availability of sheep meat in Ethiopia by approximately 7,000 tons per year. The use of anthelmintics, however, is limited by their high cost, uncertain availability, poor efficacy, difficulties in ensuring controlled grazing on communal pastures—and now, evidence of increasing resistance to them. In Australia and New Zealand, it has been conservatively estimated that total returns from sheep meat and wool will be reduced by 20–30 percent as anthelmintics lose their effectiveness.

Identification of sheep and goats that are genetically resistant to endoparasites is an attractive, sustainable, low-cost option for the control of helminthiasis. In Kenya, on the basis of total flock productivity, the resistant, indigenous Red Maasai sheep are about twice as productive as the imported Dorper sheep. Soon it may be possible to identify a DNA marker or gene for resistance to endoparasites in the Red Maasai or other indigenous tropical breeds. This discovery would have a global impact in overcoming helminthiasis in both the developing and the developed world.

Theileriosis Research (ILRAD)

ILRAD's research includes tick-transmitted theileriosis, a livestock disease caused by the parasite *Theileria parva*. In 11 countries in eastern, central, and southern Africa, 24 million cattle are estimated to be at risk from the disease annually, resulting in direct economic loss of at least \$168 million. Actual economic losses are considerably higher when the indirect costs of the disease are considered. Control strategies based on acaricides to control the vector ticks are becoming unsustainable for reasons that include the high cost of application, the development of resistance to acaricides by ticks, and the environmental hazards of intensive and widespread use of chemical acaricides.

An effective but cumbersome method of immunizing cattle against theileriosis exists. During the past five years, ILRAD has contributed significantly to the improvement of this infection and treatment method (ITM), which

relies on the use of live *Theileria* parasites. By the end of 1992, an estimated 100,000 cattle had been immunized against theileriosis, and plans are under way in a number of countries to apply the technology as a routine control measure. According to ILRAD assessments, immunization increased farm net income from cattle by up to 36 percent in indigenous breeds and up to 128 percent in improved or crossbred cattle. Total net income from cattle in the region increased by an estimated \$133–\$307 million annually.

ILRAD's theileriosis research focuses on the development of a new generation of vaccines against *Theileria parva* that will be safer and less costly than the ITM, to be ready for use in the field within the next five years. This genetically engineered vaccine is expected to reduce theileriosis immunization costs substantially, perhaps to less than 50 percent of the cost of the ITM, with greater economic returns to farmers.



African smallholder farmers, many of whom are women, can maximize returns by processing surplus milk into butter and cheese. ILCA has been improving indigenous methods for greater efficiency, such as this internal agitator—a traditional earthenware churn fitted with a wooden shaft and blades, manipulated with a string.

Higher Standards of Nutrition (ILCA)

Developing regions account for two-thirds of the world's cattle but produce only about 20 percent of global milk supplies. Research indicates that local milk production can be increased by as

much as 100 percent, through the combined efforts of NARS and IARCs to improve animal nutrition, health, genetics, production systems, and resource management. Milk production is expected to expand in East Africa, with a likely quadrupling of the region's output in the next 35 years. The subhumid and wetter semiarid agro-ecological zones of West Africa also have a high potential for market-led dairying.

The primary beneficiaries of the dairy-related research conducted by NARS and ILCA are smallholder farmers (including women), who constitute more than half of Sub-Saharan Africa's people and produce 90 percent of the staple food. In many parts of the developing world, structural adjustment programs have curbed importation of dairy products. Increasingly, the growing demand for dairy products by urban consumers must be met by domestic production. This situation presents opportunities for smallholder dairy farmers to increase household income and improve the nutrition of their families. In the long term, it is expected to lead to higher standards of living in rural areas.

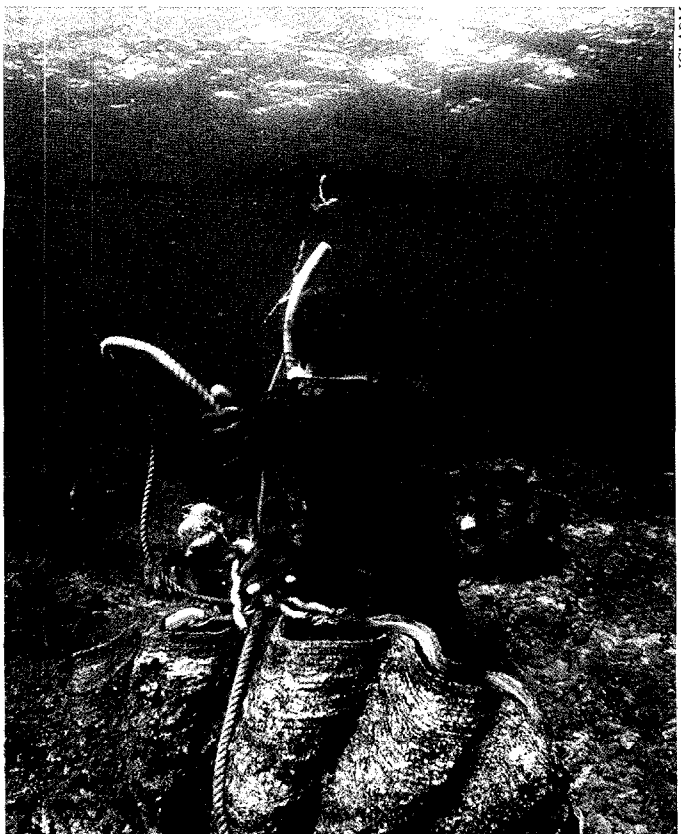
FISHERIES RESEARCH

Fisheries, aquaculture, and the related problems of the aquatic environment are important aspects of the sustainability of food production and nutrition in developing countries. Related research is the responsibility of ICLARM, which joined the CGIAR system in 1992.

Coastal and Coral Reef Resource Systems Program (ICLARM)

Three basic issues drive the urgent need for global research on coastal resource systems: overfishing, exacerbated by poverty; competition with other sectors; and pollution from them. Coral reefs are the dominant resource system in many parts of tropical seas. Their complexity, extreme biodiversity, high productivity, and fisheries potential justify a global research effort. In many regions, their degradation threatens productivity and consequent declines in food production.

For coastal resources in general, the objective is to advance fisheries management and resource use based on improved understanding



A diver prepares to take giant clam broodstock ashore for spawning at ICLARM's Coastal Aquaculture Centre in the Solomon Islands, where work on developing clam farming systems has been continuing since 1987.

of the coastal fisheries resource base, the social and economic structure of the fishing communities, and the interaction among these and other sectors. For coral reefs, the objective is to realize the potential of fisheries in a sustainable manner by improving management and by increasing the productivity of selected "new" species, notably bivalve molluscs.

Inland Aquatic Resource Systems Program (ICLARM)

The program aims to foster the sustainable use of inland aquatic resource systems by poor farmers, raising their incomes and nutritional status. The focus is on development of socially and environmentally acceptable integrated agriculture-aquaculture farming systems through research on integrated resource management and the selective breeding of tilapias and carps for good performance in farm ponds and rice floodwaters. Most adopters of the results will be "new entrants" to aquaculture in integrated resource management (especially in Africa), to use of selectively bred fish, or to both.

NATURAL RESOURCE MANAGEMENT RESEARCH

In the late 1980s, natural resource management research became the second pillar of the CGIAR's work, ranking equal with productivity research. In many instances, CGIAR research has shown that there is no conflict between sustainability and productivity objectives; proper resource management enhances the productivity of agriculture over the short and long term.

SOIL

Sustaining the Rice Resource Base in Asia (IRRI)

The intensively managed irrigated rice systems of Asia—in some areas, more than three crops a year—are only about 30 years old. Little is known yet about their long-term sustainability, but analysis of trend data indicates problems, particularly given the increased production required during the next 30 years and the limited amount of arable land available for rice production. Signs point to a decline in total productivity; more input is needed to reap the same output.

IRRI scientists interpret these symptoms as indicating a decline in the quality of the basic resource—soil. The key questions include whether the negative trends are common features in the intensively managed rice systems, what processes are at work, and how these processes can be mitigated by knowledge-based management. Currently, water inputs and nutrients are increasing efficiency and minimizing environmental damage to intensive irrigated systems, and a simple chlorophyll meter is being used to determine the nitrogen needs of plants, thus improving the efficiency of nitrogen use by a factor of 50 percent.

Protecting the Uplands (IRRI)

The upland ecosystems of the humid tropics are being devastated by logging of forests, population pressure, and agricultural intensification. Intensive cultivation leads to rapid leaching of soil nutrients, soil acidification, and erosion. The results are land degradation and soil loss from erosion, which affect not only the uplands but the watershed and ultimately the productive



Grevillea robusta trees growing alongside maize in the trials at ICRAF's research station at Machakos, Kenya. In semiarid conditions where crop production is difficult, trials have demonstrated that up to 5 extra tons of biomass per hectare per year may be produced from these trees at virtually no cost in crop yield. The increase in biomass production results from better use of rainfall by the combination of trees and crops rather than crops alone.

lowlands. Poor farmers have two choices: to move to the urban slums or to use new land.

Upland farming need not lead to land degradation. To stabilize upland rice ecosystems, current research focuses on limited adoption of knowledge-based local systems; rice varieties improved for weed competition, resistance to blast, and tolerance to drought with yields of up to 3.5 tons per hectare; land use systems that reduce annual erosion losses from 200 to 20 tons per hectare of soil; and crop management that progresses from exploitative cropping systems toward biodiverse, sustainable systems.

Halting Decline in Soil Fertility (ICRAF)

Reversing the decline in soil fertility—which farmers identify as their most pressing problem—may be the highest priority for land use planning in developing countries. ICRAF is investigating the management of fallows to improve soil fertility through fast-growing leguminous trees as an alternative to natural fallow, continuous cropping, or purchased fertilizer.

The trees capture atmospheric nitrogen and other nutrients from the lower soil layers, making them available in the topsoil through leaf litter, and improve the physical properties of the soil by root penetration. In southern Africa, after tree fallows of only one or two years, maize grain yields are as much as twice the yields from control plots and 60 percent higher than yields from plots treated with inorganic fertilizers. Even higher yields have been obtained over several years where mulch from the trees was combined with fertilizer applied at half the recommended rate. Moreover, the fallows trees produce large quantities of fuelwood, thus reducing the pressure on neighboring forests.

Initial results from Cameroon, Kenya, and Zambia indicate that this technology may be applicable to farmers in a wide variety of locations and environments in the humid lowlands of West Africa, the highlands of eastern and central Africa, and the unimodal plateau of southern Africa, which encompass more than half of Sub-Saharan Africa's rural population. On-farm and on-station experiments are ad-

addressing the applicability of results across sites, reducing the costs of planting through direct seeding and relay cropping, and the sustainability of yields over extended periods.

Erosion Control on Slopes (ICRAF)

Every year approximately 5 million hectares of cultivable land—0.3 percent of the total cultivated area in the world—are lost through erosion. It has been estimated that in Africa, soil erosion could reduce agricultural production by 25 percent by the year 2000 if conservation measures are not adopted. ICRAF is investigating erosion control on slopes by the use of hedgerows along contours to contain runoff, form natural terraces, increase production of the crops between the hedges, and provide by-products to diversify and enrich the economy of the farm. In long-term studies conducted in Kenya on 14-degree slopes, natural terraces have been formed by contour hedgerows of cassia and *Leucaena*. In these trials, the hedgerows have conserved 82 percent of the runoff and prevented 98 percent of erosion losses compared with sole crops during infrequent but intensive rainstorms. Trials have also demonstrated the controlling effect of hedgerows on slopes of up to 45 degrees in other areas in eastern Africa.

Research is focusing on selecting appropriate tree species for controlling erosion and generating by-products, regimes for managing different species and systems, understanding the interactions between trees and crops, and assessing the effects of terrace scouring.

Multipurpose Tree Windbreaks (ICRISAT)

Overexploitation of trees and shrubs in the fragile ecosystem of the West African Sahel, where agriculture is characterized by low-input technology, is resulting in near-irreversible degradation of soils susceptible to wind and water erosion. Multipurpose tree windbreaks have the potential to protect soils against erosion and rehabilitate the environment. Collaborative ICRISAT research with ICRAF and NARS will result in simple, low-cost techniques to establish trees and shrubs. Adoption by farmer communities should result in improvement and rehabilitation of soil resources and the environment by 2005.



Water flow monitoring in the Punjab, Pakistan.

WATER

Managing Water Resources (IFPRI)

The availability and allocation of water for agricultural production are expanding problems throughout the developing world, where there are conflicting demands for water for agriculture, industry, and household use. The result has been degradation of the water resource base. IFPRI has initiated research with collaborators in Egypt, India, Jordan, and Mexico on innovative methods for allocating water within agriculture and between agriculture and other uses. This research covers the feasibility and effectiveness of delegating water management to users as well as the economic and institutional feasibility of creating tradable property rights in water.

Irrigation Management Transfer in Latin America (IIMI)

Through a two-year collaborative activity in the Andean region of Latin America, IIMI will view the irrigation management transfer phenomenon from both the public and private perspectives, tracing its interrelatedness with the environmental degradation of the watershed sources of irrigation water. The study will help test two assumptions: that privatization leads to improved management and increased productivity, and

that improved resource management can help to overcome watershed degradation, thus reversing the decline in irrigation investment. The proposed program will develop guidelines for the creation of better management minidistricts to minimize degradation of watersheds and adverse impacts on downstream water quality and quantity.

Irrigation for Sustainable Agriculture in Pakistan (IIMI)

For the next five years, IIMI will help Pakistani organizations adopt management changes to mitigate the negative effects of salinity and sustained waterlogging, which include reduced food supplies and income at the household level and depressed agricultural productivity at the national level. Pakistan has previously focused on technological solutions at the expense of expanding institutional capacity.

The project seeks to redress this imbalance through a series of provincial studies designed to yield specific management recommendations. In particular, it targets disadvantaged irrigators, such as tail-end farmers, who have not only water supply problems but lower incomes, fewer benefits in relation to labor costs, weaker influence in their communities, and less access to services than farmers at the head.

Watershed-Level Participatory Management In Sri Lanka (IIMI)

A six-year project to increase the share of users' control over land and water resources in selected watersheds recently began in Sri Lanka. The project will facilitate state-user partnerships that contribute to intensified and sustainable agricultural production while conserving the physical, biological, and social environment. In the first phase, with IIMI facilitation, the inhabitants of two watersheds are working with the government to prepare a detailed land and water management plan. Using known technologies, the plan will seek to augment the resource base while improving production through management changes. It will also strengthen user groups so that they can experiment with innovative "production and protection" methods of natural resource management. This site-specific activity will contribute to global IIMI research on participatory approaches to environmentally sustainable water management.

FOREST AND AGROFORESTRY RESEARCH

Rain Forest Clearance (ICRAF)

Approximately 17 million hectares of tropical rain forest are lost every year. This loss is estimated to be responsible for 15–25 percent of global warming through the emission of 1 billion tons of carbon a year. ICRAF is coordinating a global effort to find alternatives for the 300 million people caught in the poverty trap of unsustainable slash-and-burn practices, which account for about two-thirds of tropical deforestation. The impact of this initiative should be visible within 15–20 years to the subsistence farmers in rain forest areas, as well as to members and supporters of the consortium.

Forestry Research (CIFOR)

CIFOR aims to improve management of forest lands by unifying the divergent research on policy and biophysical issues. Major gains are foreseen from improved decision making on forests and from better adoption of improved policies. Better application of ecological research to the problems of managing natural forests is expected to increase the return on investment significantly. Management will improve for diverse products and services, emphasizing nontimber products of benefit to local communities and global products such as biodiversity.

The potential to increase yields of forest products, particularly timber from plantations of degraded lands, is enormous. The key lies in better matching of genotypes with sites, which requires the development of techniques to streamline species and provenance testing. Rapid increases in productivity will result from research on the physiological processes involved in tolerance to environmental stress and more efficient use of light, water, and nutrients, and on the physiological and molecular bases of rejuvenation for application in vegetative propagation.

Saving Forests Through Improved Agricultural Policies (IFPRI)

Millions of acres of tropical forests are being cut down by small- and medium-scale farmers in Brazil, Indonesia, Philippines, and Africa who need agricultural land for their families' survival. Government efforts to slow the cutting of forests



IPGRI is collaborating with the International Network for Bamboo and Rattan in a Japan-funded project for the genetic conservation of these important nontimber forest products.

for agriculture have largely failed. IFPRI, in collaboration with Brazilian counterparts, NGOs, and farmers, is undertaking research in the western Brazilian Amazon, where deforestation is severe, to identify factors that influence how farmers make decisions about forest and land use. This research will help government policy makers in South America, Africa, and Asia design and implement policies and programs that slow the pace of forest destruction for agricultural use while improving human welfare.

GENETIC RESOURCES MANAGEMENT RESEARCH

Cryopreservation (IPGRI)

New advances in techniques for cryopreservation (conservation in liquid nitrogen at -190°C) offer the promise of a safe and long-term storage option for species that cannot be stored as seeds, including many tropical species such as root and tuber crops. IPGRI is collaborating with many partner institutions in the development of effective cryopreservation technologies.

Genetic Markers (IPGRI)

Advances in the use of biochemical and molecular genetic markers are giving scientists a better picture of the extent of genetic diversity in nature and its distribution. The information gained from such techniques will permit better targeting of field collection and identification of sites for

in situ conservation, and will be useful in monitoring changes in genetic diversity under different management regimes.

Coconuts (IPGRI)

Coconuts—the “tree of life” for millions of people, especially in Asia, coastal regions of Africa and Latin America, and Pacific and Caribbean islands—have been largely neglected by the international research community. An initiative by IPGRI aims to support the efforts of partner institutions to study and evaluate coconut germplasm, to set up appropriate conservation systems, and to organize the international exchange and testing of elite coconut types that have the potential to improve smallholder agriculture.

Germplasm Collection (ICARDA)

To conserve the genetic variability of wheat and its progenitors, extensive collections were made where wheat originated—in the newly independent republics of Uzbekistan, Tadjikistan, Turkmenistan, and Armenia. Valuable *Aegilops* (a precursor to wheat) and natural *Aegilops* x wheat crosses were collected and preserved for current and future needs of plant breeders.

International Rice Germplasm Center (IRRI)

Conservation of genetic resources in perpetuity is an important foundation for permanency in agriculture; it is also inextricably linked with

containment of environmental degradation. A large part of the world's genetic resources of rice conserved at IRRI's International Rice Germplasm Center, which contains about 74,500 accessions of *Oryza sativa*, 1,200 of *O. glaberrima*, and 2,100 of wild species at Fort Collins, Colorado, in the United States. It has been estimated that the addition of 1,000 accessions to the rice genebank generates more than 14 new rice varieties worldwide with a value of \$325 million annually, and that an additional landrace introduced to the genebank is worth \$50 million each year.

The genebank will continue to collect and disseminate new genetic materials, including wild species that may be endangered; develop *in situ* conservation methods in collaboration with NGOs to ensure the evolving diversity of rice; and use molecular biotechnology to characterize the gene diversity of the collection.

Germplasm Exchange and Use (IRRI)

The International Network for the Genetic Evaluation of Rice (INGER) organizes and manages the international exchange and evaluation of promising varieties, elite breeding lines, and genetic donors, making more genetically diverse cultivars available to farmers. INGER is primarily a conduit of new varieties: 58 entries in INGER nurseries have been released since 1988 as varieties in 18 countries in Asia, Africa, and Latin America. It has been estimated that each released entry has a value of \$2.5 million annually and that the INGER nursery has a value of \$105 million annually.

Of the 1,709 modern varieties released worldwide, 390 were borrowed through INGER; about 75 percent of all new varieties grown worldwide have one parent identified through INGER. Genetic diversity of cultivars has increased three-fold because of these exchanges, and IRRI has provided 75 percent of the pedigrees for this genetic diversity.

Aquatic Biodiversity (ICLARM)

Two data bases are being developed in collaboration with numerous agencies: "FishBase" documents fish biodiversity on a global basis; "ReefBase" will document the coral reef systems of the world. Within a few years, FishBase will be in use in compact disc form in many

developing countries' fisheries laboratories, greatly facilitating research and management efforts. Data acquisition systems for coastal fisheries and coral reef fisheries will be established and in use at various sites. Software for improved management of multispecies fish stocks is already in use in several hundred institutions in developing countries. In several years, additional analytical software will be available that will greatly enhance prospects for management of tropical fish communities, and thus increase, or at least sustain, harvests.

Conservation of Biodiversity (ILCA)

Covering only 22 percent of the Earth's land-mass, Africa holds 48 percent of the world's natural pastures, 14 percent of the cattle, and 25 percent of the sheep and goats. More than 90 percent of Africa's ruminant population is indigenous: Africa has more than 80 relatively unknown cattle breeds or strains, and probably even more of small ruminants. Sub-Saharan Africa is also the center of origin of 30,000 plant species. ILCA holds nearly 13,000 accessions of forage legumes and grasses, including the indigenous *Trifolium*, *Sesbania*, *Cynodon*, *Panicum*, *Cenchrus*, and *Digitaria* spp.

Current research in plant genetic resources aims to characterize a range of forage germplasm for nutritional value, productivity, and adaptability to the environmental conditions in the semiarid, subhumid, and cool tropical regions of Africa.

About 500 accessions of forages are added to the ILCA collection annually, and methods for improved germplasm storage and seed multiplication will be developed. Indigenous animal genetic resources are systematically characterized for their production and unique adaptation traits, such as tolerance of heat and water stress. The information obtained improves the use of productive forage and animal resources in farming systems.

Conserving the genetic diversity of Africa's indigenous plants and animals is of global importance, as evidenced in the 1960s by the successful transfer of *Cynodon dactylon* var. *elegans* to the United States (developed as Burton's Coastal Bermuda grass) and, more recently, by the introduction of Africa's *Boran* and *Tuli* cattle breeds to invigorate the Australian beef industry.



This Philippine rice farmer, a cooperater in the ICLARM-International Institute of Rural Reconstruction project on integrated agriculture-aquaculture system, has, within a few years, constructed a series of eight springfed fish ponds. Vegetables and fruit trees are now grown between and around the ponds.

RESOURCE MANAGEMENT TECHNOLOGY AND METHODOLOGY

East African Highlands (ILCA)

About 62 percent of the densely populated East African highlands—home to 30 percent of Africa's human population—are in Ethiopia, where poor farming practices cause losses of 2–3.5 billion tons of soil annually. As crop yields fall, the risk of crop failures and famine worsens. Inappropriate land use practices upstream in the Ethiopian highlands can have serious consequences for Sudan, Eritrea, and Egypt.

Working in an East African consortium of national and international partners, ILCA is developing profitable, ecologically sound, land-intensification technologies to increase incomes and food availability in the highlands. This research is expected to lead to intergenerational resource equity and improve the environmental safety of the lowlands that are served by rivers originating in the East African highlands.

Integrated Resource Management (ICLARM)

ICLARM is pioneering farmer-scientist research partnerships to study the integrated use of natural resources available to farming households and

communities. New breeds of fish will become part of these resources as the GIFT (Genetic Improvement of Farmed Tilapias) project, INGA (International Network on Genetics in Aquaculture), and national breeding programs proceed. This approach requires new research methods and tools and interdisciplinary research in three areas: transformation of small farms to sustainable integrated agriculture and aquaculture; ecological and bioeconomic modeling; and evaluation of social, economic, and institutional factors necessary for adoption and retention of this approach by new entrants. Outreach work-sites are in Sub-Saharan Africa (Malawi, the lead country for inland aquaculture for the Southern Africa Development Community sub-region) and South Asia (Bangladesh) and proposed for Southeast Asia (the Philippines and Vietnam). A West African initiative has been deferred because of inadequate funding.

Sustaining Rice Production (IFPRI, IRRI)

Although the green revolution technologies developed during the 1960s and 1970s enabled farmers in developing countries to meet the increasing food demands of their growing populations, maintaining and increasing yields in a sustainable manner in coming decades poses an even greater challenge. Future gains will depend

on farmers having access to new technologies that they are able to adapt these technologies to their own environmental conditions. Government officials will have to identify policies and incentives to encourage farmers to adopt environmentally sound practices. Since the 1980s, farmers in Asia have been experiencing a slowdown in the growth of rice productivity and degradation of their land. The long-term decline in the world rice price has reduced investments in irrigation, research, and extension. Intensive monoculture rice farming has led to salinity and waterlogging, toxic soils, hard soils, soil nitrogen deficiencies, and increased crop losses caused by pest resistance. IFPRI is collaborating with IRRI and researchers in Bangladesh, China, India, Indonesia, Pakistan, the Philippines, and Thailand to examine appropriate policies for reversing degradation and sustaining rice productivity growth. This research will help policy makers develop appropriate pricing policies and priorities for rice research and irrigation, extension, and capital investments.

Natural Resource Management and the Environment (ISNAR)

In the coming decade, virtually all NARS will become more involved in natural resource management and the environment. Because such research by nature spans disciplines as well as economic sectors, NARS have begun to request assistance in the integration, organization, and management of this new area. By mid-1995, ISNAR is expected to produce quantitative indicators of sustainability for use in NARS. Such indicators not only will help today's farmers protect irreplaceable natural resources but will benefit future generations of farmers, who will be challenged to produce food for rapidly growing populations on long-used and sometimes degraded lands.

Applications of a Geographical Information System (ICRISAT)

ICRISAT is using a GIS to integrate such factors as soil type, length of growing season, area, production, crop value, and population to identify primary agroecological zones. Expected payoffs in these zones can be calculated with the aid of overlays of yield constraints and the probabili-

ties of success of research interventions. Integrating poverty measures with populations facilitates consideration of equity concerns. Results will be displayed as simple, color-coded maps that show the potential for success. These maps, which can also be used to identify where populations are ecologically and environmentally disadvantaged, will be available to national and regional planners and policy makers.

Fragile Lands Research (IFPRI)

During the past 20 years, scattered, successful local efforts have encouraged farmers to invest in rehabilitation of fragile areas such as those found in the steep slopes and hillsides of Central America and in nonirrigated dryland areas of the Sahel. Government policy makers, however, have been unable to replicate these efforts on a national scale. In many cases, they have inadvertently discouraged such practices. IFPRI's fragile lands research will help government policy makers identify strategies that support and expand these local successes. For example, Honduras is reforming its forest and water laws with few empirical data to guide policy decisions. IFPRI, with Honduran research institutions and development agencies, will undertake research to show the likely effects of various policy options on agricultural production, poverty alleviation, and environmental stability.

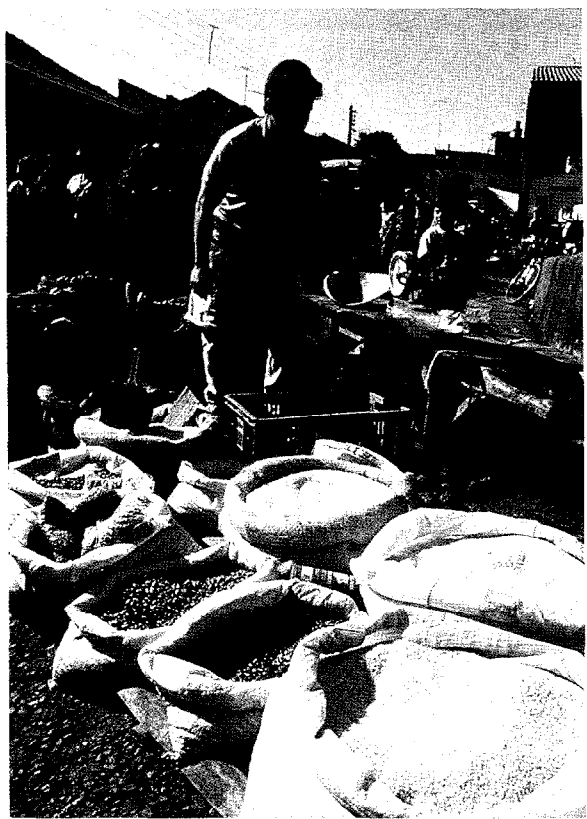
SOCIOECONOMIC AND POLICY STUDIES

Although technical research to improve agriculture, fisheries, and forestry is important, it alone cannot ensure sustainable development of the food and agriculture sector. The CGIAR is therefore providing its clients—governments of developing countries and their national agricultural research systems—valuable socioeconomic research, policy studies, and policy advice related to food security and agriculture.

Impact of New Technology on Women (ICARDA)

In Tunisia, women constitute 50 percent of the total agricultural labor force and 60 percent of temporary hired labor; together the two repre-

sent 20–25 million workdays per year. Winter sowing of chickpea can increase yields by 154–243 percent; however, it increases the labor requirements for weed control and harvesting. When ICARDA studied the impact of this new technology on female labor at the farm level, it found that on small, poor farms, winter sowing would increase the already heavy workload of women without increasing direct remuneration. On larger farms, however, it will create new employment opportunities for women, especially for weeding. The study also shows that this technology is neither class nor gender neutral.



Market in Piendamó, state of Cauca, Colombia. CIAT works to ensure that its research products are relevant to the communities' needs and market opportunities.

Reforming Agricultural Markets (IFPRI)

For most developing countries, the past three decades have seen heavy government intervention in agricultural markets. Not only have public interventions been expensive, they have constrained agricultural and rural development rather than fostering it. These governments are now attempting to reform their markets, which

will help to foster democratization as well. In response, IFPRI has developed an ambitious research program focused on reforming agricultural markets in developing countries, particularly in Africa. IFPRI has initiated projects in Ghana, Senegal, Cameroon, Malawi, Tanzania, and Uganda that will design market reform strategies and build the in-country capacity necessary to implement and monitor these reforms. New projects are also in final stages of development for Vietnam, Kyrgyzstan, and the Philippines and will help guide policy makers through the reform process. The impact of these reforms on monetary resources and agricultural production will be enormous. IFPRI's work on agricultural market reforms in Bangladesh and Pakistan proved that a \$3 million investment for research and training on market reform can help a government save \$124 million. In Bangladesh, 35 percent of recent increased food production was a result of market liberalization.

“Safety Nets” for the Poor (IFPRI)

In Zimbabwe more than 6 million people were vulnerable to severe hunger during the 1991–92 drought in southern Africa, yet famine did not occur because Zimbabwe's policy makers had effective employment programs that provided “safety nets” for the poor. As policy makers in other developing countries implement the economic reforms essential for future growth, they are looking for ways to protect large numbers of poor people who are vulnerable to both climatic and economic shocks. The poor are often unable to participate in emerging market economies because they lack purchasing power. IFPRI is conducting research to identify cost-effective programs that protect the poor during transition periods and allow them to participate in the economic growth process. With policy makers in Ethiopia, Botswana, Malawi, and in other parts of the world, IFPRI is working to establish similar systems over the next five years.

Increasing Micronutrients in Seeds to Enhance Diets (IFPRI)

More than 1 billion people, mostly pregnant and nursing women and young children, are at increased risk of death, blindness, or reduced cognitive ability because of deficiencies of iron,

vitamin A, iodine, and zinc in their diets. IFPRI is coordinating the research effort in the CGIAR to reduce "micronutrient malnutrition" by identifying policies to encourage the adoption of nutrient-rich diets and by coordinating research to fortify crops that are part of the diet. Research indicates that breeding crops that load more micronutrients into seeds will increase the nutritional value of the plant and its resistance to disease and drought, thus boosting yields. Wheat seeds with higher zinc content, for example, would be more vigorous, and fewer would be lost during planting. It is estimated that such wheat varieties would save Turkish farmers some \$100 million a year by lowering the seeding rate. This research effort should lead to long-term solutions to many health problems associated with the poor-quality diets of small-holder farmers and the urban poor.

Trilingual Data System for *Musa* Researchers (INIBAP)

Comprehensive compilations of bibliographies, researchers' activities, research themes, and characterization of *Musa* biodiversity are being (or will be) published for distribution to banana and plantain researchers and collection curators to provide a worldwide information system. Publications will be in English, French, and Spanish. Regular updating of the information and directories will make these instruments dynamic tools in the dissemination of knowledge and the transfer of technology for this globally important food source.

Integrating Markets in Developing Countries (IFPRI)

Regional trade integration is an area of growing importance in the economies of the world. For developing countries, the expected benefits of participating in regional trade arrangements for staple foods and other traded goods are not known. This is particularly true in southern Africa, a region undergoing major changes. In South Africa, policy makers are looking to a much different economic and political future. IFPRI will analyze the effects of recent macro-economic reforms and closer economic relations within the region in a postapartheid environment. Research will focus on the implications

for agricultural growth and rural development in the countries bordering South Africa. The research will help policy makers answer questions such as: What trade and production benefits will accompany the removal of economic sanctions against South Africa? How can these benefits be increased? What are the implications of greater regional integration on production, trade, and resource allocation in the food and agricultural sector?

RESEARCH POLICY AND MANAGEMENT

One CGIAR center, ISNAR, specializes in research on how to improve policy and management for agricultural research in developing countries. ISNAR's research and outreach program focuses on six areas seen as most critical for developing effective NARS: linkages; resources for research; policy; NARS planning and support; information; and planning, monitoring, and evaluation. An important cross-cutting theme is the integration of research on natural resources and the environment into the more traditional agricultural research agenda.

Linkages

Many technologies being produced by agricultural research organizations are not reaching farmers, especially resource-poor farmers. One principal reason is poor linkages among these research organizations, technology transfer agencies, and farmers or the organizations that represent them. ISNAR is studying the potential of farmers' organizations to act as a link between producers and research organizations. Two key roles of farmers' associations are being examined: their ability to influence the work agendas of public-sector research, groups and their capacity to work as partners with these organizations, taking on some of their functions and responsibilities.

Because it will help NARS make better use of technologies already developed, ISNAR's linkages project has a high ratio of benefit to cost. Benefits should be evident in 1995, when three case studies in Burkina Faso, Ghana, and Kenya are completed and have follow-up assistance to strengthen linkages.



CGIAR/Katryn Elzeiser

Resources for Research

Universities house considerable resources for development-oriented research in agriculture that are not being fully harnessed to solve the production problems of farmers. ISNAR has launched a project to put these resources to work for the benefit of producers and national agricultural development. Concrete examples of the strengthened collaborative roles of universities will be visible in Nigeria and Benin by mid-1995, when action plans developed with these two countries will be implemented. The project will also help developing countries to broaden their agricultural research agendas to include the environment and the production resource base.

Policy

Whether national agricultural research thrives or fails depends heavily on the policy environment in which it operates. ISNAR is conducting policy research in three particularly important areas: the impact of structural adjustment on NARS; the roles of public- and private-sector organizations in conducting agricultural research in developing countries; and collection, analysis, and synthesis of statistical briefs that quantitatively trace the recent evolution of Africa's NARS. Each of these efforts is expected to produce concrete benefits by mid-1995.

NARS Planning and Support

One of ISNAR's central tasks is to respond to specific requests from NARS in developing countries for support in the planning, organization, and management of their agricultural research. Such support includes diagnostic reviews of research organizations and systems and advice on strengthening specific management components. Human resource management, financial management, research priority setting, and information management are all examples of such components.

Information

Regional networks and organizations have been promoted strongly in recent years. Despite the number of networks, established NARS in many developing countries continue to lack valuable information. Appropriate information can help researchers collaborate effectively in regional programs and help an organization to focus on areas in which it has a clear comparative advantage. In 1994, ISNAR launched a project to help NARS access the networks and information they need while avoiding "network overload." The project's initial focus is on establishing a joint mechanism for coordinating and managing networks, to save thousands of hours of researchers' time and the resources now used on experiments that overlap or duplicate work carried out elsewhere.

Planning, Monitoring, and Evaluation

Increasingly, their sponsors and clients are asking agricultural research institutes for transparency and accountability in their operations, as well as for better management. Improving planning, monitoring, and evaluation (PM&E) is an essential step toward achieving these goals. ISNAR is concluding a two-year, \$1.5 million project to strengthen agricultural research management in Latin America and the Caribbean. Four Spanish-language training modules form the basis of a five- to six-day course to help research managers improve PM&E in their organizations. These trained specialists can now be called on to provide PM&E training at NARS institutes. This project methodology and the training materials will be adapted for use in Asia and Africa.

CGIAR Finances—1993

Each year the CGIAR Secretariat reports on the CGIAR's financial performance in the preceding year, based on the centers' financial statements. The CGIAR 1993 Financial Report, available from the CGIAR Secretariat and summarized here, provides comprehensive financial information for all 18 centers.

A number of organizational developments occurred in 1993 that relate directly to the centers' and donors' operations.

ORGANIZATIONAL DEVELOPMENTS IN THE CGIAR

With the start-up of CIFOR activities in Indonesia, the number of centers in the system increased to 18 in 1993. At its 1994 Mid-Term Meeting, the CGIAR approved the integration of INIBAP's operations into those of IBPGR, which becomes the International Plant Genetic Resources Institute (IPGRI) in 1994. The International Livestock Research Institute (ILRI), a new global livestock center, will be formed through the merger of ILCA and ILRAD.

The development phase for the Medium-Term Plan (1994–98) ended in 1993, and the CGIAR received recommendations from its Technical Advisory Committee (TAC) at International Centers Week (ICW) 1993. The substance of the Medium-Term Plan was endorsed by the CGIAR; however, formal approval was made conditional on the availability of adequate funding.

The CGIAR created two donor committees: the Finance Committee, which will provide advice and recommendations for the efficient management of the system's finances, and the

Oversight Committee, which will ensure that the system has appropriate governance policies and instruments in place. Both committees are composed of representatives drawn from the system's donors.

In 1993, the Association of International Agricultural Research Centers (AIARC) became fully operational. The CGIAR centers established AIARC as a collaborative enterprise to administer their employee benefits program.

The centers collaborated with each other and with TAC at diverse levels in 1993. Notable in the finance area was a workshop held in June 1993, at which most centers were represented. A number of initiatives were discussed, and guidelines for enhanced financial procedures emerged. Among them were a revised accounting policy document, overhead recovery practices, improved financial management guidelines, purchasing power analysis, and audit practices for the CGIAR centers.

FINANCIAL HIGHLIGHTS

Financial resources (grants and other income) available to the centers in 1993 totaled \$318 million, 5 percent lower than total 1992 revenue. The centers reported aggregate operating expenditure of \$323 million, virtually the same as in 1992. The resulting net operating deficit of \$5 million represents 1.6 percent of total 1993 income for the CGIAR.

Table 1 summarizes many of the important CGIAR financial data for the period 1990–93. This snapshot illustrates not only the sources of funds available to the centers but how they have been used. The table shows the data for both core and total programs of the CGIAR. In addition, it shows broad indicators of international development assistance and the CGIAR

Note: All dollar amounts are in current U.S. dollars. Totals in text and illustrations are computer-rounded.

Table 1. CGIAR Financial Indicators, 1990–1993 (US\$ millions and percent)

	1990		1991		1992		1993	
	Core	Total	Core	Total	Core	Total	Core	Total
Resource Summary (dollars)								
<i>Grants</i>								
CGIAR Contributions	234.9	287.9	231.9	291.1	247.3	318.7	234.7	311.3
Percent of Annual Change	5	6	(1)	1	7	9	(5)	(2)
<i>Other Revenue</i>								
Stabilization Fund	2.5	2.5	4.7	4.7	0.0	0.0	0.0	0.0
Adjustment, World Bank Grant	0.0	0.0	0.0	0.0	1.9	1.9	(4.1)	(4.1)
Other Income (net)	19.5	19.5	13.8	13.8	18.4	14.2	18.4	11.0
Total Revenue	256.9	309.9	250.4	309.6	267.6	334.8	249.0	318.2
<i>System Expenditure^a</i>								
Operations	231.9	280.7	248.4	295.1	258.7	318.5	254.1	321.4
Capital	17.6	26.6	0.0	11.1	0.0	7.4	0.0	1.9
Total Expenditure	249.5	307.3	248.4	306.2	258.7	325.9	254.1	323.3
<i>Net Surplus/(Deficit)</i>	7.4	2.6	2.0	3.4	8.9	8.9	(5.1)	(5.1)
Net, as Percent of Revenue	2.9	1.0	0.8	1.1	3.3	2.7	(2.0)	(1.6)
<i>Miscellaneous</i>								
Core Funding, Percent of Total	82		82		78		75	
Percent of CGIAR Funds								
Unrestricted	83	68	84	69	82	63	83	63
CGIAR Grants as Percent of ODA	0.44	0.54	0.41	0.51	0.41	0.52	0.43	0.57
Number of Contributing								
CGIAR Donors	33		39		36		38	
Expenditure Share Profile (percent)								
<i>Program (operations)</i>								
Research Programs	46	45	46	47	49	49	48	49
Research Support	10	13	10	8	10	9	9	8
Training/Communications	18	18	18	22	16	20	15	19
Research Management	26	24	27	23	27	22	28	24
<i>Region (operations)</i>								
Sub-Saharan Africa	42	...	43	...	39	42	37	39
Asia	30	...	29	...	33	31	34	35
LAC	16	...	15	...	16	17	15	15
WANA	13	...	13	...	12	11	13	11
<i>Object</i>								
Personnel	54	...	58	...	57	52	59	54
Supplies/Services	32	...	28	...	30	33	28	34
Travel	7	...	6	...	6	8	6	6
Depreciation	0	...	8	...	7	6	7	5
Capital	7	...	0	...	0	2	0	1
CGIAR Financial Indicators (dollars)								
Total Assets		401.0		405.9		434.6		435.8
Fixed Assets		215.2		214.5		215.7		220.8
Operating Fund		39.9		35.9		38.0		35.4
Capital Fund		4.7		11.8		25.6		34.1
Other Funds		12.8		10.2		8.9		7.5
Asset/Liability Ratio		1.6		1.6		1.6		1.8
Memo Items:								
Centers' Cost Deflator (1993 = 1)		1.05		1.01		0.99		1.00
IMF Deflator of OECD countries (1993 = 1)		1.10		1.06		1.03		1.00
Total ODA (actual US\$ billions; 1993 is estimate)		53.0		56.7		60.8		54.8
Number of Centers		13		13		18		18

Note: ODA, official development assistance; LAC, Latin America and Caribbean; WANA, West Asia and North Africa; IMF, International Monetary Fund; OECD, Organization for Economic Cooperation and Development.

a. Effective 1991, core capital expenditures flow through the capital fund financed by annual depreciation provisions that are included in the operating expenditures. Complementary capital expenditures are shown as expenses to the extent they are not subjected to depreciation.

share of it, inflation data, and data on the centers' financial position.

1993 FUNDING

Core Grants

In 1993, 75 percent of grant funding to the CGIAR was for the core component of the centers' programs, which represents the CGIAR's essential activities. The donors' core grants of \$235 million were 11 percent below the level approved (\$264 million) at ICW 92, and 5 percent below actual 1992 core funding. Table 2 shows the distribution of CGIAR core funding by center for the period 1990–93.

In 1993 the number of core donors to the CGIAR increased to 38, from 36 in 1992. Indonesia joined the CGIAR, supporting three centers, and Luxembourg became a contributing donor again. The decrease in funding volume, combined with the increase in the number of donors, resulted in a 10 percent decline in average contribution per donor in 1993.

Table 3 provides details of core program contributions to the CGIAR by individual donor for the period 1990–93. All contributions from non-dollar sources have been converted to U.S. dollars, at the exchange rate in effect when the centers received the contributions.

Unrestricted funding represented 83 percent of all core grants and 63 percent of total system funding in 1993. Ten donors provided 85 percent of all unrestricted grants. In descending order, these donors were the United States, the World Bank, Japan, Canada, the European Community, the United Kingdom, Germany, Switzerland, the Netherlands, and Sweden. Excluding the World Bank, the remaining nine donors provided two-thirds of unrestricted core funding.

Balancing Support

In 1993, as in the past, the role of World Bank funding was to provide funds to individual centers to narrow the gaps between support from other donors and the centers' approved budgets. In 1993, 86 percent of disbursement from the balancing fund was required for 10 centers, which each needed more than 15 percent of their funding from the World Bank. In 1992, nine centers required more than 15 percent of

their funding from the balancing facility, and their aggregate share of World Bank funds disbursed in 1992 was 73 percent. This change demonstrates one effect of overall decreased core funding.

Disbursement Schedule

The donors' disbursement of funds continued to lag behind the minimum levels required to cover the next quarter's expenses for the centers, as shown in Figure 1. By midyear (June 30), only about one-third of the funds had been disbursed to the centers. In fact, if the World Bank had not disbursed \$36 million in January 1993, some centers would have faced severe cash-flow problems until the latter half of the year. This disbursement lag is an important reason why the centers require and maintain financial reserves.

Complementary Grants

The 1993 funding of complementary activities amounted to nearly \$77 million, 7 percent more than in 1992. This increase continued the trend in recent years of expansion in noncore funding, in both absolute terms and as a share of the total. The increase came from both CGIAR donors and non-CGIAR donors, which include nongovernmental organizations, universities, and private companies.

Centers' Total Funding

Figure 2, showing the total funding for each center in 1993, indicates the relative importance of the core and complementary components to each center's overall program. Compared with 1992, many centers remained in the same relative position in terms of total funding. However, the most significant changes involved ICRAF and IBPGR, which both moved up the scale several places. ILCA and ILRAD also moved down the scale, by several places.

CGIAR EXPENDITURES

Table 1 provides a system-wide summary of expenditure shares, expressed as percentages, by program (such as research management), by region, and by object (such as personnel costs and operational travel expenses). In addition to these major categories, system operations can

Table 2. CGIAR Core Funding by Center, 1990–1993 (US\$ millions)

<i>Centers</i>	<i>1990</i>	<i>1991</i>	<i>1992</i>	<i>1993</i>
CIAT	27.7	27.9	26.9	25.3
CIFOR			3.2	5.1
CIMMYT	27.1	26.6	26.1	23.1
CIP	16.9	17.1	15.3	14.7
IBPGR	7.0	8.1	9.0	8.6
ICARDA	18.7	19.5	17.9	16.2
ICLARM			4.5	3.8
ICRAF			11.1	11.2
ICRISAT	31.5	29.4	27.3	26.0
IFPRI	9.1	8.9	8.3	8.1
IIMI			6.4	6.1
IITA	22.5	22.4	21.7	20.8
ILCA	20.2	19.4	15.8	11.8
ILRAD	13.6	13.5	12.6	10.4
INIBAP			1.8	1.8
IRRI	29.8	29.8	28.6	26.3
ISNAR	7.0	7.6	7.0	6.1
WARDA	6.2	6.7	5.8	5.4
Subtotal	237.4	236.7	249.2	230.6
Net Flow from Stabilization Fund	-2.5	-4.7		
Applied to 1993 Programs			-1.9	1.9
To Be Allocated				2.2
Total CGIAR	234.9	231.9	247.3	234.7
<u>Memo Items:</u>				
1. Complementary Grants	53.0	59.1	71.4	76.6
2. Total Grant Funding	287.9	291.0	318.7	311.3

Note: Columns may not total precisely because of rounding.

be shown as expenditure according to the activity classification used by TAC in analyzing and describing CGIAR priorities and strategies (referred to as “TAC activities”). The classification of TAC activities was also used in the development of the centers’ 1994–98 Medium-Term Plans.

Table 4 is a dollar and percentage summary of core program and total activities for the CGIAR in 1992 and 1993. To provide a meaningful description of how the centers use their resources, overhead costs such as research support and research management have been included in the activity categories according to a standard allocation formula.

Overall, 1993 saw a significant increase over 1992 in resources allocated to research on eco-

system conservation and management (3 percentage points, which is a 27 percent increase). Research on conservation and management of natural resources (Activity 1) overall increased by 1 percentage point. Little change occurred in Activity 2 (germplasm enhancement and breeding), and a slight decrease in research on production systems development and management (Activity 3) occurred for the core programs. Expenditure for Activity 4 (socioeconomic, public policy, and public management research) and Activity 5 (institution building) remained virtually in the same proportions as in 1992.

Because of the decreased funding in the CGIAR in 1993, staff numbers declined. Except for several of the newer centers, personnel numbers at all levels decreased, including both inter-

Figure 1. Disbursement of Funds by Donors, 1993

(Cumulative percentages, optimal versus actual timing)

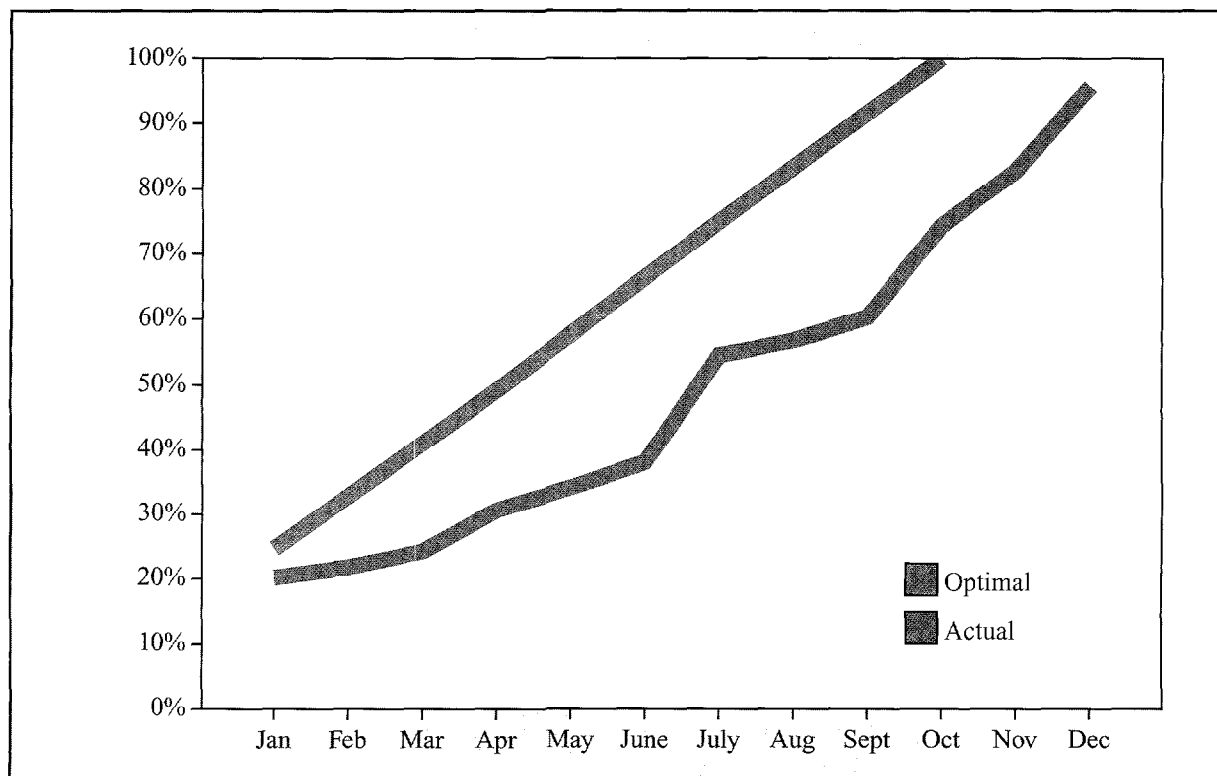


Figure 2. CGIAR Core and Complementary Funding by Center, 1993 (US\$ millions)

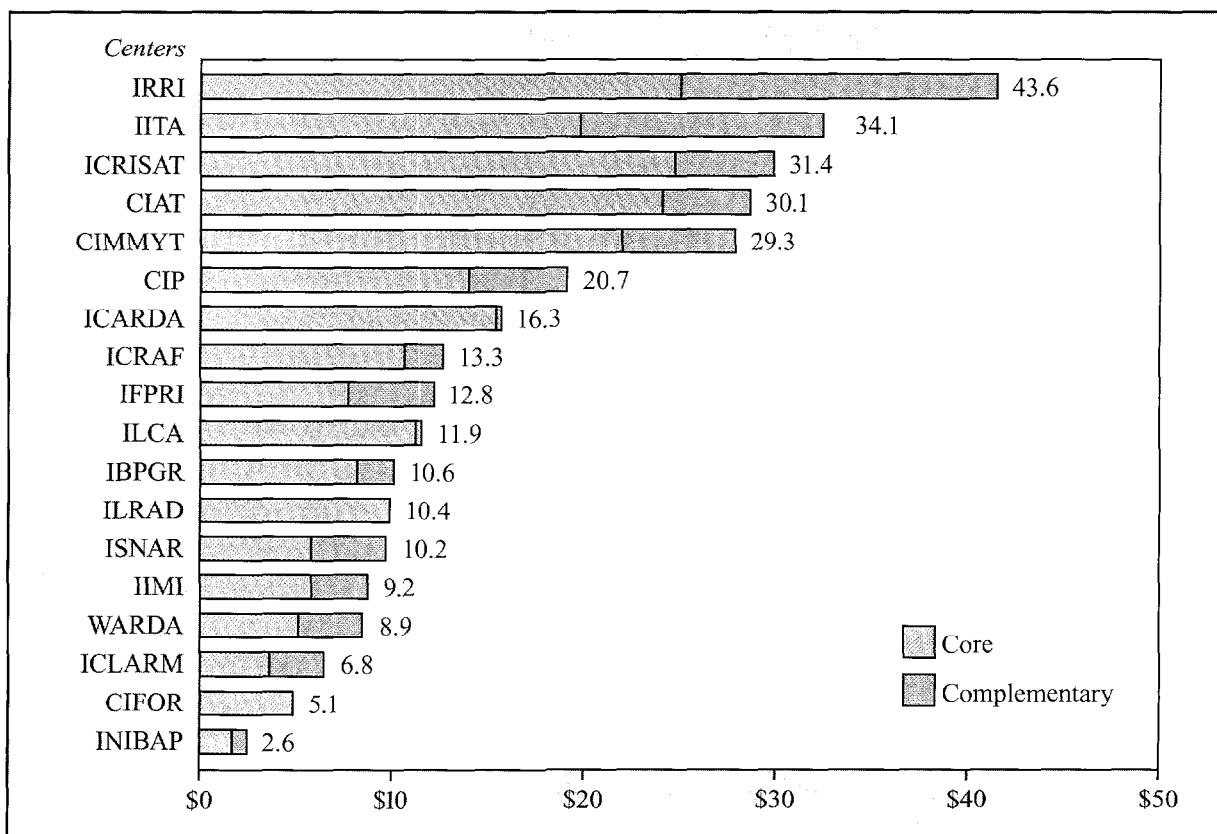


Table 3. CGIAR Members Ranked by Core Contributions, 1990–1993 (US\$ millions)

<i>Rank</i>	<i>1990</i>		<i>1991</i>		<i>1992</i>		<i>1993</i>	
#1	U.S.	45.09	U.S.	45.63	U.S.	48.12	U.S.	40.47
	World Bank	34.33	World Bank	35.11	World Bank	37.62	World Bank	40.00
	Japan	23.19	Japan	23.70	Japan	26.89	Japan	32.61
	EC	15.41	Canada	15.73	Canada	17.55	Canada	15.75
	Canada	15.35	EC	13.45	Germany	13.71	Germany	13.27
	U.K.	11.57	U.K.	11.57	EC	13.33	EC	12.09
	Germany	11.20	Germany	11.04	U.K.	11.10	Switzerland	9.18
	IDB	10.50	Switzerland	10.16	Switzerland	10.60	U.K.	9.42
	Switzerland	9.38	UNDP	6.64	Sweden	8.62	Netherlands	8.34
#10	Netherlands	6.89	Netherlands	6.45	Netherlands	7.64	UNDP	7.27
	UNDP	6.33	IDB	6.31	UNDP	6.87	Sweden	6.22
	Sweden	6.20	Italy	6.07	Norway	5.83	IDB	5.07
	Italy	6.10	Sweden	6.07	Italy	5.80	Denmark	4.79
	Finland	5.31	Finland	5.91	IDB	5.11	Norway	4.65
	Norway	4.70	Norway	4.68	France	4.91	Australia	4.24
	France	4.10	France	4.10	Denmark	4.86	Italy	3.90
	Australia	3.81	Denmark	3.39	Australia	4.38	France	3.18
	Denmark	3.57	Belgium	3.31	Belgium	3.30	Belgium	2.52
	Belgium	3.16	Australia	3.17	Ford	1.75	Ford	2.25
#20	Rockefeller	1.74	AfDB	1.55	Rockefeller	1.47	Austria	1.50
	AfDB	1.23	Ford	1.18	Austria	1.05	AfDB	1.07
	Austria	1.00	Austria	1.00	Finland	1.01	Rockefeller	0.85
	Ford	0.94	Rockefeller	0.90	IDRC	0.89	Arab Fund	0.72
	IDRC	0.78	Arab Fund	0.64	ADB	0.79	Ireland	0.66
	ADB	0.63	IDRC	0.54	Arab Fund	0.62	Spain	0.62
	Spain	0.50	India	0.50	Spain	0.62	IFAD	0.58
	IFAD	0.50	Korea	0.50	Korea	0.50	China	0.50
	India	0.50	Spain	0.50	China	0.50	India	0.50
	Ireland	0.31	IFAD	0.36	India	0.50	Indonesia	0.50
#30	China	0.30	Ireland	0.34	IFAD	0.41	Korea	0.50
	Philippines	0.20	ADB	0.31	Ireland	0.34	IDRC	0.49
	Nigeria	0.09	China	0.30	AfDB	0.23	Philippines	0.27
	Brazil	0.01	Luxembourg	0.25	Philippines	0.22	Finland	0.24
	Arab Fund	0.00	Philippines	0.20	OPEC Fund	0.11	ADB	0.22
	UNEP	0.00	Nigeria	0.12	Mexico	0.04	Luxembourg	0.13
	Mexico	0.00	OPEC Fund	0.12	Nigeria	0.03	OPEC Fund	0.10
	OPEC Fund	0.00	Mexico	0.10	Brazil	0.00	UNEP	0.04
	Kellogg	0.00	Brazil	0.09	Kellogg	0.00	Nigeria	0.02
	Leverhulme	0.00	UNEP	0.03	Luxembourg	0.00	Mexico	0.01
#40	Saudi Arabia	0.00	Kellogg	0.00	Saudi Arabia	0.00	Brazil	0.00
			Saudi Arabia	0.00	UNEP	0.00	Kellogg	0.00
	Total	234.91	Total	232.02	Total	247.29	Total	234.73

Table 4. CGIAR Research and Research-Related Expenditures, 1992–1993

(US\$ millions and percentages)

	1992				1993			
	Core		Total		Core		Total	
	dollars	percent	dollars	percent	dollars	percent	dollars	percent
ACTIVITY 1								
Conservation and Management of Natural Resources								
Ecosystem Conservation and Management	29.7	11	34.3	11	35.8	14	43.8	14
Germplasm Collection, Conservation, Characterization, and Evaluation	19.9	8	21.6	7	14.7	6	17.2	5
Total Activity 1	49.6	19	55.9	18	50.5	20	61.0	19
ACTIVITY 2								
Germplasm Enhancement and Breeding								
Crops	56.7	22	65.3	20	56.2	22	66.3	21
Livestock	2.0	1	2.0	1	1.1	0	1.1	0
Trees	1.9	1	2.1	1	1.8	1	2.0	1
Fish	0.7	0	1.0	0	0.7	0	1.0	0
Total Activity 2	61.3	24	70.4	22	59.8	24	70.4	22
ACTIVITY 3								
Production Systems Development and Management								
Cropping Systems	40.0	15	50.1	16	37.5	15	48.4	15
Livestock Systems	21.1	8	21.2	7	20.3	8	20.4	6
Tree Systems	3.9	2	4.4	1	4.9	2	5.5	2
Aquatic Systems	1.1	0	1.6	1	1.0	0	1.8	1
Total Activity 3	66.1	26	77.3	24	63.7	25	76.2	24
ACTIVITY 4								
Socioeconomic, Public Policy, Public Management Research	25.5	10	33.0	10	24.8	10	32.3	10
ACTIVITY 5								
Institution Building								
Training and Conferences	22.4	9	31.9	10	19.5	8	28.2	9
Documentation, Publications, and Information Dissemination	19.9	8	21.6	7	22.3	9	24.9	8
Organization and Management Counseling	5.8	2	14.0	4	7.5	3	17.5	5
Networks	8.0	3	14.6	5	6.0	2	10.8	3
Total Activity 5	56.1	22	82.0	26	55.4	22	81.4	25
Total Expenditures	258.7	100	318.5	100	254.1	100	321.4	100

Note: Columns may not total precisely because of rounding.

nationally and locally recruited staff. In 1993, total staff numbers decreased 10 percent from 1992. Internationally recruited staff reached a high of 808 for core programs in 1992, when the five expansion centers joined the CGIAR. In 1993, the number declined by 3 percent; however, the 1993 decline for the original group of centers from 1989 levels, when this group's staff numbers were at their highest, was 10 percent. Because more than half of the system expendi-

ture is for personnel costs, funding decreases should result in a reduction in this category of expenditure as the overall activity level declines. However, there is a time lag before the full savings on salaries and benefits can be realized, because there is a significant transaction cost to separation of personnel. The centers' actions to reduce the size of the payroll will start to pay off in financial terms—with savings—in future years.

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**Published by the Consultative Group on International Agricultural Research,
CGIAR Secretariat, 1818 H Street, N.W., Washington, DC 20433, United States.
Telephone (1-202) 473-8951. Fax (1-202) 473-8110. October 1994. ISSN 0257-3156.**

